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THE FOUNDATIONS OF NUTRITION

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ANTOINE LAURENT LAVOISIER
Father of the Science of Nutrition

THE FOUNDATIONS OF NUTRITION

BY

MARY SWARTZ ROSE, Ph.D.

PROFESSOR OF NUTRITION, TEACHERS COLLEGE
COLUMBIA UNIVERSITY

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PREFACE

Anyone can learn to run an automobile by rule. "Turn on the gas, start the engine with clutch in neutral, release the brake" has been mastered by hundreds of thousands who know very little about electricity or theories of mechanics; who never pause to consider how the battery starts the motor or how the gasoline is converted into power. Nevertheless, great numbers of automobile owners have found it to their advantage to study the mechanism of their cars because it saves money in upkeep and repairs; it often saves time in waiting for some one to help in an emergency; and it may save much strain on the car, prolonging its life and increasing its period of service.

Much the same can be said of the human machine. Everybody knows that food is required to run it, but the appetite is such a reliable "self-starter" for food consumption that no one has to be taught what to do with a plate of attractive viands. Like running an automobile driving can be done by rule of thumb, without any understanding of what the food is doing to the body beyond the passing pleasure of the meal; or it can be managed with intelligence and foresight, avoiding in course of time many disabilities and saving the body unnecessary wear and tear, which insidiously but inevitably cut down its efficiency and impair the value of the individual to himself and to society.

This book is written for those who wish to live more intelligently. An effort has been made to present within a small space some of the fundamental principles of human nutrition in terms which call for no highly specialized training in those natural sciences upon which the science of nutrition rests. The selection of topics and the relative amount of space devoted to each are based on much experience in

presenting the subject of nutrition to beginners whose object is to be well informed as to the significance of food in daily life so that they may order their own lives more successfully and may have a better understanding of the part which nutrition plays in health in the world at large.

Each essential factor in an adequate diet is discussed in detail with many references to animal experiments which help to make clear the reasons why it must have a place in the daily program. The foods which serve the best purpose of these essentials have been indicated, and a very practical new method of comparing nutritive values of common food materials has been described with many concrete examples.

The reading references at the end of each chapter have been chosen for their availability and clearness. For the sake of those who may wish to enter into a very thorough study of the subject, references to original literature have been included as footnotes throughout the text.

The author wishes to express her very great appreciation of the encouragement and valuable criticism received from Professor Henry C. Sherman and also of many helpful suggestions from other members of the Department of Nutrition of Teachers College. Special acknowledgments are due to Dr. Margaret C. Hessler and Miss Hazel K. Stiebeling for their coöperation in the development of the simplified method of denoting food values presented in Chapters XI and XII. Dr. Hessler was the first to suggest the use of the term "share" to indicate the amount of protein or of any mineral elements which should accompany each 100-calorie portion of a normal family dietary, and Miss Stiebeling very kindly prepared the "share" table in the Appendix.

Special thanks are due to Dr. Edgar J. Smith for the privilege of reproducing a rare portrait of Lavoisier, and to others who have kindly aided with the illustrations.

M. S. R.

FOREWORD

A living being considered as an object of chemical research, is a laboratory, within which a number of chemical operations are conducted; of these operations, one chief object is to produce all those phenomena, which taken collectively are denominated LIFE; while another chief object is to develop gradually the corporeal machine or Laboratory itself, from its existence in the condition of an atom, as it were, to its utmost state of perfection. From this point of utmost perfection the whole begins to decline as gradually as it had developed; the operations are performed in a manner less and less perfect, till at length the being ceases to live; and the elements of which it is again set free, obey the general laws of inorganic nature.

JÖNS JACOB BERZELIUS
1779–1848

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CHAPTER I

HISTORICAL INTRODUCTION

SECTION I

SOME LANDMARKS IN THE DEVELOPMENT OF THE SCIENCE OF NUTRITION

The idea that there is a close connection between man's diet and his well-being is no innovation of the twentieth century. In an ancient chronicle we may read: "In the third year of the reign of Jehoiakim, king of Judah (607 B. C.) came Nebuchadnezzar, king of Babylon, unto Jerusalem, and besieged it." When the city fell into his hands, the king ordered that certain noble youths, "well-favored and skilful in all wisdom," be selected for training as courtiers. They were to have a special education and a daily portion of the king's meat, and of the wine which he drank. Living a carefully prescribed life, at the end of three years they would presumably be fit to stand before the great monarch. One of these youths "with knowledge and skill in all learning and wisdom" objected to the dietary part of the program and purposed in his heart that he would not eat the king's meat nor drink his wine; but the prince of the eunuchs, who had him in charge, protested, saying, "I fear my lord the

king." The young man countered with a reasonable proposal: "Prove thy servants, I beseech thee, ten days; and let them give us pulse to eat and water to drink. Then let our countenances be looked upon before thee, and the countenance of the youths that eat of the king's meat." This seemed a fair bargain and so the nutrition experiment was undertaken, with the result that at the end of the ten days "their countenances appeared fairer and fatter in flesh than all the children which did eat the portion of the king's meat. So the steward took away their meat and the wine which they should drink and gave them pulse;" and when at the end of their probationary period the king examined them they passed with a score ten times better than all the magicians and enchanters in his realm.[1]

What Becomes of Food Eaten?

From that time to this, man has given much thought to the problem of where food goes when it is eaten and what it does to the one who eats it. But for many centuries the answers to such questions were philosophical rather than scientific. The greatest philosopher among the ancients with regard to food was Hippocrates, the famous priest of Æsculapius officiating in the celebrated Health Temple of Cos in Greece in the day of Socrates and Plato, who by his wisdom and skill earned the title of Father of Medicine. The historian Strabo says that he was trained in dietetics, and some of his aphorisms have a modern sound, for example: "Growing bodies have the most heat; they

[1] *Daniel* I: 1–15.

therefore require the most food, for otherwise their bodies are wasted. In old persons the heat is feeble and therefore they require little fuel, as it were, to the flame for it would be extinguished by much." (Aphorism 14.)[1] But Hippocrates and his successors for two thousand years accounted for the disappearance of food as "insensible perspiration" and "heat" without any real understanding of what either term meant.

Fig. 2.—Sanctorius on the steelyard which he devised to weigh himself before and after meals.

In 1614 A. D. a university professor with a practical turn of mind devised a chair connected with a steelyard to weigh himself before and after meals, so that he might find out the amount of this "insensible perspiration," for he said: "He only who knows how much and when the body does more or less insensibly perspire will be able to discern when or what is to be added or taken away, either for the recovery or the preservation of health." (Aphorism 3.)[2] Even Sanctorius's painstaking efforts did not solve the mystery because in his day there was no science of chem-

[1] Adams, Francis. *Genuine Works of Hippocrates*, page 197. William Wood and Co. (1891).

[2] Lusk, Graham. *Science of Nutrition*, 3d edition, page 18. W. B. Saunders Co. (1917).

istry. This did not begin its active development until about half a century later.

Air is Essential for Life

In 1627 was born the Honourable Robert Boyle, seventh son of "the great Earl of Corke," destined to receive the best education of his day in England and on the continent and to become known to every student of chemistry or physics as a result of his studies on the "weight and spring of the air." In the course of his extensive investigations of the properties of the air, he conducted a large number of "pneumatical experiments about respiration." He put into the receiver of his "pneumatical engine" all sorts of small animals—"a kitling newly kittened," "a duckling that was yet callow," "a large and lusty frog"—to find out "whether there reside in the heart of animals such a fine and kindled, but mild substance, as they call a Vital Flame, to whose preservation, as to that of other flames, the Air (especially as is taken in and expelled again by respiration) is necessary," and he found that it was necessary, as the following experiment will serve to indicate:

"Experiment I. We included in a round vial with a wide neck (the whole glass being capable of containing about 8 ounces of water) a young and small mouse, and then tied strongly upon the upper part of the glass's neck a fine thin bladder, out of which the air had been carefully expressed, and then conveyed this phantastical vessel into a middle-sized receiver, in which we also placed a mercurial gage (adjusted by our elsewhere mentioned standard); this

done, the air was by degrees pumped out, until it appeared by the gage, that there remained but a fourth part in the external receiver (as for distinction sake I call it) whereupon the air in the internal receiver expanding itself, appeared to have blown the bladder almost half full, and the mouse seeming ill at ease by his leaping, and otherwise endeavoring to pass out at the neck of his uneasy prison; we did, for fear the over thin air would dispatch him, let the air flow into the external receiver, whereby the bladder being compressed, and the air in the vial reduced to its former density, the little animal quickly recovered."[1] So this ardent chemist demonstrated to his full satisfaction the dependence of animals upon the air they breathe for life.

Still more significant respiration experiments were made by a young chemist named John Mayow, who came under the influence of Boyle and in 1668, at the age of twenty-eight, published a "Treatise on Respiration" in which he showed that if a burning candle and an animal be put together in a bell jar both will expire sooner than either one alone. Mayow seems to have been the first to recognize that breathing brings the air into contact with the blood. He wrote: "Air loses somewhat of its elastic force during respiration by animals as also in combustion. One must believe that animals, like fire remove from air particles of the same nature."[2] Mayow's death at the age of thirty-four delayed the development of true conceptions of respiration for nearly a hundred years.

[1] *Works of Robert Boyle*, Vol. 3, page 128. A. Millar (1744).

[2] Lusk, Graham. "History of Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 10. D. Appleton and Co. (1922).

The Gases of Respiration

In 1754 a young Scotchman named Joseph Black, who was studying medicine at the University of Edinburgh, published his inaugural dissertation for his M. D. degree on the subject of magnesia and quicklime; substances in which he was specially interested because the medicines in vogue for the cure of gallstones all seemed to derive their efficacy from quicklime. He had discovered that a cubic inch of marble yielded about half its weight of pure lime and "as much air as would fill a vessel holding six wine gallons." His lectures were published after his death from his manuscript notes, and his biographer wrote in the preface: "It was not only a most unexpected and curious thing to find that a matter so solid and impenetrable as marble could appear in the form of air, and this air be again put into our hands in the form of marble; but this new acquaintance had properties which forcibly called for the most serious attention. This air can be poured from one jar into another like as much water; and when it is poured out on a candle, or even on a fire in sufficient quantity, they are extinguished in an instant, as if water had been poured on them. . . . It has also been discovered that this air, so destructive and salutary, is forming in vast quantities every moment around us."[1] He called it "fixed air," a little later to be identified as carbon dioxide. He also found that limewater was made cloudy by breathing into it through a tube, as well

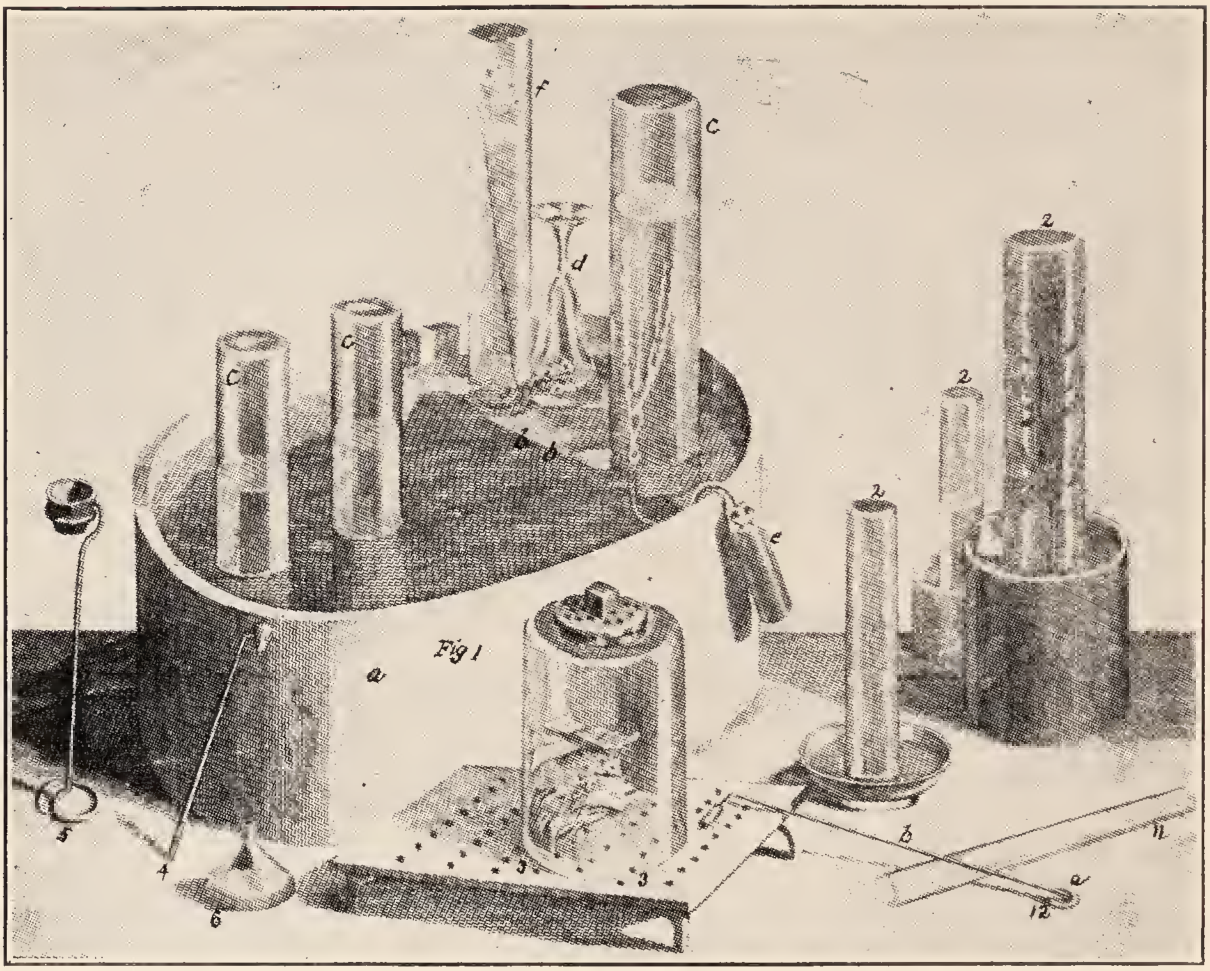
[1] Lectures on the Elements of Chemistry, delivered in the University of Edinburgh by the late Joseph Black, M. D., Professor of Chemistry in that University. Published from his manuscripts by John Robison (1807).

as by shaking it in a jar in which a candle had just gone out, and concluded that the breathing of animals changes "common air" into "fixed air."

While Black was winning renown as a professor in the University of Edinburgh and a devoted following as a practicing physician in the city, a dissenting clergyman in England, by the name of Joseph Priestley, was earning his living by acting as librarian for a rich patron but devoting all his spare time to chemical experimentation.

Priestley took a living plant (a sprig of mint) and put it into a closed receptacle in which a candle had already burned out. After several days another candle was introduced into the same jar and this time it did not go out but burned brightly. Soon after this, he took a jar, filled it with mercury, and carefully inverted it in a vessel containing mercury, so that no air entered the jar. He then introduced through the opening, under the mercury, some red oxide of mercury, which rose and floated on top of the mercury inside the mouth of the jar. Upon this he converged the heat of the sun by means of a powerful burning glass, and this is how he described the result: "I presently found by means of this lens air was expelled from it (the mercuric oxide) very rapidly. Having got about three or four times the bulk of my materials, I admitted water and found that it was not imbibed by it. But what surprised me more than I can well express was that a candle burned in this air with a remarkably brilliant flame." [1] Priestley had discovered a new gas,

[1] Priestley, Joseph. *Experiments and Observations on Different Kinds of Air*, Vol. 2, page 107. Thomas Pearson (1790).



(*Courtesy of the New York Public Library*)

Fig. 3.—Apparatus Used by Priestley.

Plate and description from "Experiments and Observations on Different Kinds of Air" (1790).

"I first used an oblong trough made of earthenware, Plate 1, Fig. 1, about 8 inches deep, at one end of which I put some flat stones, about an inch or half an inch, under the water, using more or fewer of them according to the water in the trough. I afterwards found it more convenient to use a larger wooden trough of the same form, with a shelf about an inch lower than the top, instead of the flat stones above mentioned. In one end of this trough are ledges on which it can slide. . . . The several kinds of air I usually keep in cylindrical jars, as C, C, Plate I, Fig. 1, about 10 inches long, and 2½ inches wide. . . . If I want to try whether an animal will live in any kind of air, I first put the air into a small vessel, just large enough to give it room to stretch itself; and as I generally make use of mice for this purpose, I have found it very convenient to use the hollow part of a tall beer-glass, *d*, Fig. 1, which contains between two and three ounce measures of air. In this vessel a mouse will live 20 minutes or half an hour. . . . In order to keep mice, I put them into receivers open at the top and bottom, standing upon plates of tin perforated with many holes, and covered with other plates of the same kind, as Plate 1, Fig. 3. . . . In the same manner in which a mouse is put into a vessel of any kind of air, a plant, or anything else may be put into it, viz., by passing it through the water. . . . When I want to try whether any kind of air will admit a candle to try to burn in it, I make use of a cylindrical glass vessel, Plate 1, Fig. 11, and a bit of wax candle, *a*, Fig. 12, fastened to the end of a wire, *b*, and turned up in such a manner as to be let down into the vessel with the flame upwards."

given off by the growing plant and by the heated mercuric oxide, which the candle flame fed upon so readily.

At almost the same time a similar experiment had been performed by a Swedish apothecary named Scheele, who called the gas which he had discovered "fire air." Scheele next took two bees, put them in a chamber with a little honey, connected the chamber with a glass cylinder filled with the "fire air," and immersed its lower end in limewater. Day by day the limewater rose in the tube and the volume of this gas diminished, until at the close of a week the limewater nearly filled the cylinder and the bees were dead. The "fire air" had been used up by the bees and the carbon dioxide given off by them was absorbed by the limewater which filled the space originally occupied by the "fire air."

FIG. 4.—Scheele's apparatus showing bees in the upper chamber of a glass apparatus filled with oxygen.

Respiration a Measure of Food Burning in the Body

Priestley and Scheele were both in communication with a brilliant young French nobleman, Antoine Laurent Lavoisier, a member of the French Academy of Science. At their urgent request, he repeated their experiments, confirming the discovery that "fixed air" was carbon dioxide and giving to "fire air" the name of oxygen. Lavoisier then proceeded on his own account

to demonstrate how living animals affect the air. He took a sparrow, shut it up in a small chamber and concluded from his observations that oxygen disappeared from the air and that after the animal had died the carbon dioxide which it produced could all be absorbed from the chamber by limewater. Then Lavoisier and the great physicist Laplace together took another step forward. They put a guinea pig into a chamber and measured for ten hours the carbon dioxide formed by its respiration. This was found to equal that produced by burning in a closed vessel 3.33 grams of carbon. Next the guinea pig was confined for ten hours in a chamber containing a known weight of ice, and the quantity of ice melted by the animal's body was determined. This required for its melting almost exactly the same amount of heat as was evolved in burning the 3.33 grams of carbon. The obvious conclusion was that the carbon dioxide formed by the guinea pig came from burning in its body the equivalent of 3.33 grams of carbon.[1]

Similar observations were subsequently extended to human subjects, and drawings made by Mme. Lavoisier from memory after her husband's death in 1794 show Lavoisier's associate, Seguin, sitting in a chair breathing through a mask into a series of globes by means of which the oxygen consumed and the carbon dioxide given off were measured. Lavoisier came to the conclusion that "respiration is only a slow combustion of carbon and hydrogen, which is similar in all respects to that which takes place in a

[1] A slight discrepancy was accounted for in the reduction of the guinea pig's body temperature by the cold.

lamp or lighted candle; and from this point of view the animals which respire are truly combustible bodies which burn and consume themselves."[1] Because of his grasp of the significance of the respiratory process in relation to food, Lavoisier is accounted the father of the science of nutrition.

SECTION 2

METHODS AND APPARATUS FOR THE MEASUREMENT OF ENERGY TRANSFORMATION IN THE BODY

Ice and Water Calorimeters

Lavoisier was the first investigator who applied the balance and the thermometer to the study of vital

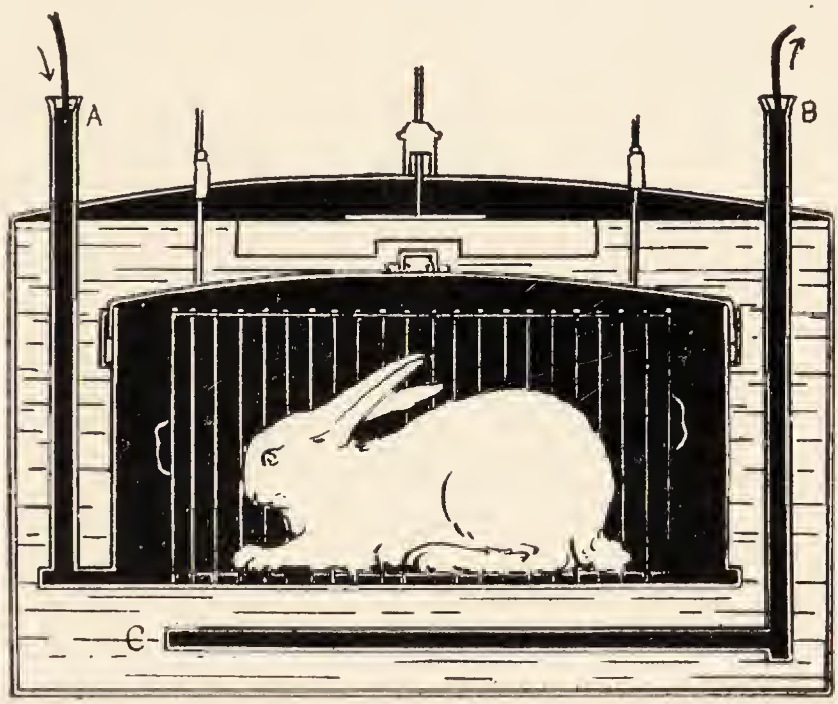


FIG. 5.
A Water Calorimeter of 1823.
The inner chamber containing the animal was submerged in a larger receptacle filled with water. Air entered at A, circulated through a coil under the inner chamber, and connected at C with the exit pipe B. Thermometers extending into the water recorded the rise in temperature caused by the animal.

phenomena. His work with Laplace on the measurement of the heat production of a guinea pig has already been mentioned; the ice calorimeter which they de-

[1] Cited by Mathews, A. P. *Physiological Chemistry*, 2d edition, page 294. William Wood and Co. (1916).

vised for this purpose is still preserved in Paris. After Lavoisier's death the French Academy offered a prize for further investigation and two young men, Dulong and Depretz, entered the lists. They improved upon Lavoisier's methods, putting small animals into a chamber surrounded by water to absorb the heat and weighing the carbon dioxide and the water given off from the animals' bodies. Dulong won the prize (1823), although Depretz's work appears now to be somewhat superior.

The Measurement of Respiration

In 1849, Regnault, professor of physics at the University of Paris, with his assistant, Reiset, constructed

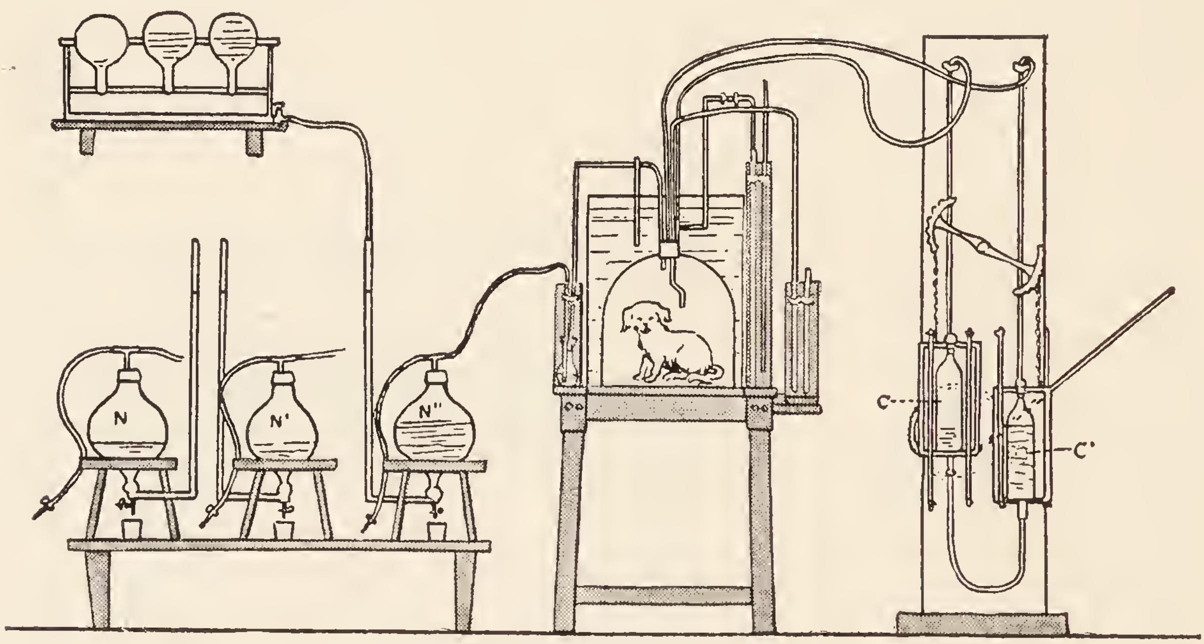


FIG. 6.—Respiration Apparatus of Regnault and Reiset.

Oxygen was supplied to the animal from a large flask, N″. (N and N′ are other flasks in reserve.) Water pressure from the flasks above at the left drove the oxygen into the apparatus. An exit tube from the chamber containing the animal is connected with bulbs for absorbing carbon dioxide, C and C′. (From *Annales de Chimie et de Physique*, Series 3, Vol. 26, plate III, 1849.)

an apparatus which enabled him to keep small animals respiring normally in an enclosed space. The subject was placed in a glass case containing a known quantity

of oxygen, which was replenished as it was consumed and the air in the apparatus was continually pumped through a solution which took out the carbon dioxide exhaled. By means of this device, Regnault was able to show that eating different kinds of food made a difference in the amount of oxygen used and in the amount of carbon dioxide excreted. He also noticed that the small animals absorbed more oxygen and produced more heat and more carbon dioxide in proportion to their size than did the larger ones—sparrows ten times as much as chickens; that cold-blooded animals consumed less oxygen per unit of body weight than did warm-blooded; and insects much more than reptiles: for example, beetles consumed 0.96 liter of oxygen per kilogram per hour and silkworms 0.84 liter, while frogs and earthworms only about 0.10 liter. Regnault and Reiset hoped to study man in the same way, but the apparatus proved too expensive for them.

The Nature of Body Fuel

Liebig, born at the opening of the nineteenth century, was the first to understand clearly that the substances oxidized in the body are organic carbon-bearing compounds of three types, protein, fat, and carbohydrate; and he showed that one gram of fat requires for complete combustion 2,050 cubic centimeters of oxygen, and one gram of starch 832 cubic centimeters—values nearly those in use to-day.

The Regularity of Heat Production

Bidder and Schmidt, two Germans working at the University of Dorpat (then in Russia), at about the

same time (1850), concluded that for every species of animal there is a typical minimum of necessary metabolism, which is apparent in experiments when no food is given. "The extent of the respiration, like every other component of the metabolism process, is to be regarded as a function of one variable, the food taken, and one constant, a distinctly typical metabolism, which varies with the age and sex of the individual. This factor characterizes every animal of given race, size, age, and sex. It is just as constant and characteristic as the anatomical structure and the corresponding mechanical arrangement of the body." [1]

The First Respiration Chamber

Ten years later, Voit, then professor of physiology at the University of Munich, suggested to the physicist Pettenkofer, head of the hygienic laboratory of the city of Munich, that he devise a respiration apparatus which would accommodate a fairly large dog. Pettenkofer aspired to work with men, however, so he constructed (1862) an air-tight chamber as large as the stateroom of a steamer, in which a man could live with comfort. It was ventilated by means of pumps which drew air from the outside. The air was aspirated through the chamber, and at the point of exit samples were measured, after having been passed through suitable solutions for the removal of carbon dioxide and water.

These two men, Voit and Pettenkofer, working together with this apparatus established many points

[1] Lusk, Graham. "History of Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 63. D. Appleton and Co. (1922).

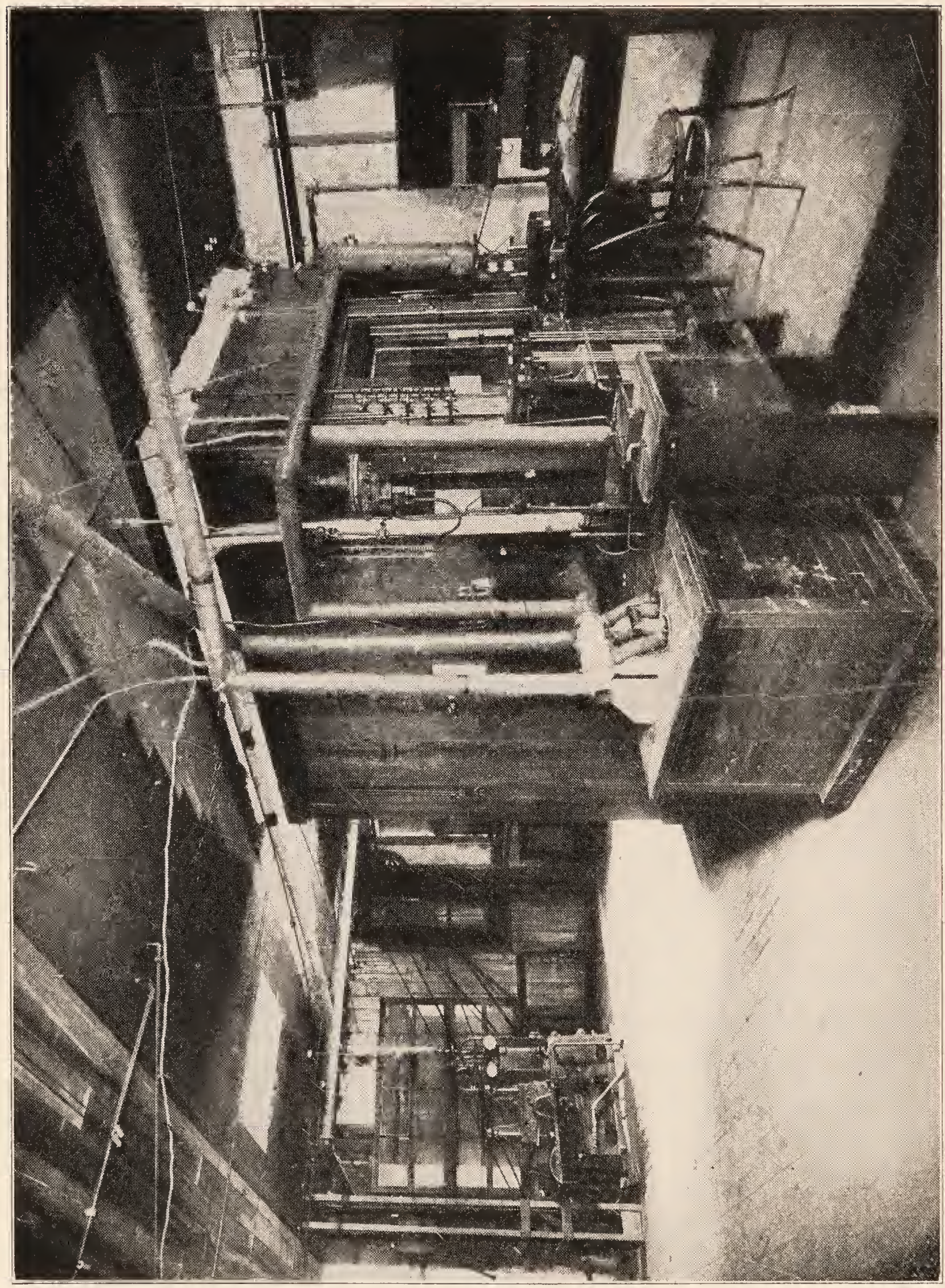
hitherto uninvestigated or obscure. Rubner, later one of the masters of the science of nutrition, found while working as a pupil in Voit's laboratory that the energy values to the body of starch and fat were equal to the heat produced by burning them in a special apparatus for heat determinations, called a calorimeter; but that the energy value of protein was different, since it could not be as completely burned in the body as it could in the calorimeter. The values which Rubner [1] established for protein, fat, and carbohydrate are still current, although figures derived by Atwater [2] from studies upon human beings seem more suitable for calculations such as are indicated in this book.

The Law of Conservation of Energy in the Animal World

Rubner became professor of physiology at Marburg and in 1892 in his own laboratory evolved a calorimeter large enough for a dog, which very accurately measured the heat production of the animal. This was connected with a Pettenkofer-Voit respiration apparatus, and the heat measured by the calorimeter exactly corresponded (within one per cent) to the heat calculated from the measurement of the oxygen intake, carbon dioxide output, and losses of energy-bearing material in urine and feces. Thus, one hundred years after its initial conception by Lavoisier, Rubner established by animal experimentation the fundamental

[1] One gram of protein, 4.1 calories; one gram of fat, 9.3 calories; one gram of carbohydrate, 4.1 calories.

[2] One gram of protein, 4 calories; one gram of fat, 9 calories; one gram of carbohydrate, 4 calories.



(*Courtesy of the United States Department of Agriculture*)

Fig. 7.—Atwater's Respiration Calorimeter.

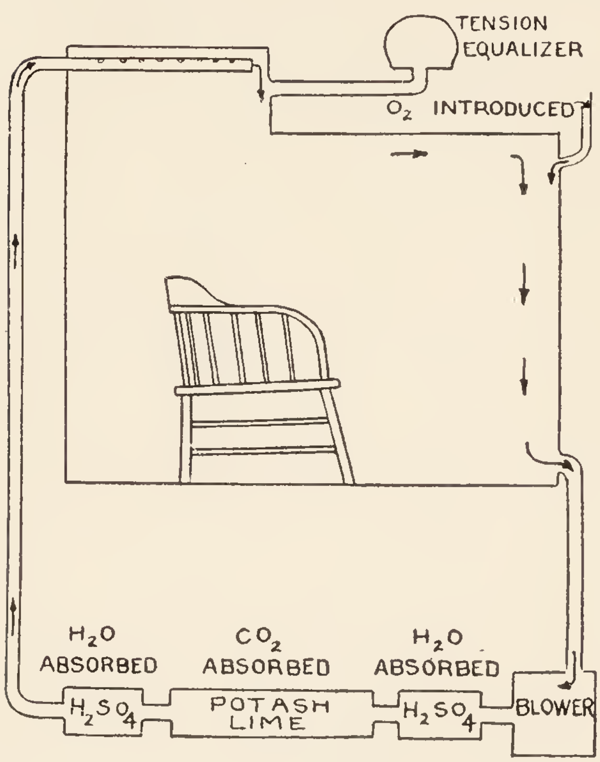
law that energy is neither created nor destroyed in the animal body.

The Respiration Calorimeter in America

While Rubner was engaged in these researches in Germany, Atwater, also at one time a pupil of Voit and later professor of chemistry at Wesleyan University, Middletown, Connecticut, began to work upon a respiration calorimeter which was brought to perfection in association with the expert physicist, Rosa. This calorimeter enabled him to carry out on man such experiments as Rubner was conducting on dogs. The respiration part embodied the principles of the Regnault-Reiset apparatus; the heat-measuring part depended upon removing the body heat as fast as produced, by means of a current of cold water, thus maintaining a comparatively constant temperature in the chamber. Improvements were soon instituted by Benedict, and to-day the Atwater-Rosa-Benedict respiration calorimeter represents the highest perfection in this type of apparatus.

The apparatus consists of an air-tight copper chamber surrounded by zinc and wooden walls with air spaces between. Gain or loss of heat through the metal walls of the chamber is prevented by keeping the zinc wall at the same temperature as the copper, so that there will be no exchange of heat between them. Provision is made both for heating the inner air space by electricity and for cooling it by water current. Protection is afforded by the outer air space against changes in the temperature of the air of the laboratory. Between the copper and the zinc walls are placed a

large number of thermoelectric junctions connected with a delicate galvanometer by which each wall is tested every four minutes, day and night, during the progress of an experiment. There is no possibility of passage of heat through the walls of the chamber influencing the results. The ventilating air current is so regulated that there is no difference in the temperatures of the incoming and the outgoing air. The heat evolved by the subject is mostly absorbed by a current of cold water passing through a pipe coiled near the ceiling of the chamber, although a small quantity leaves as latent heat of water vapor. The amount of heat removed from the chamber by the cold water passing through the heat absorbers is computed from the amount of water that flows through the pipe and its rise in temperature during its passage.



(*Courtesy of Dr. F. G. Benedict*)

FIG. 8.—Chair Type of Respiration Calorimeter.

The arrows show the circulation of the air, which is kept in motion by the blower. Water (H_2O) is absorbed by the sulphuric acid (H_2SO_4) and carbon dioxide (CO_2) by the potash lime.

The space for the subject is large enough for him to stand or lie at ease and move about somewhat. It is furnished with metal chair, table, and bed, all of which may be folded and put away when not in use. An opening in the front, sealed during the experiment, serves as both door and window. In the opposite wall

is a smaller aperture, used for passing food, drink, excreta, etc., in or out of the chamber. Tightly fitting caps close each end. There is a telephone for communication with persons outside.

The perfecting of the respiration calorimeter for human experiments opened a new era in nutrition in this country. Calorimeters were built in Washington by the United States Department of Agriculture; at the Pennsylvania State College, by Armsby; in New York, by Lusk, for Cornell University Medical College and the Russell Sage Institute of Pathology; in Boston, by Benedict, for the Carnegie Institution of Washington. These men and their associates have made signal contributions to our knowledge of energy requirements, many of which will be referred to later.

The Modern Portable Respiration Apparatus

The conclusive demonstration, by means of the respiration calorimeter, that energy calculated from the amounts of carbon dioxide excreted and oxygen absorbed by a man lying quietly in the apparatus exactly equals the heat given off by his body in the same period, has made it possible to dispense with the actual measurement of body heat (direct calorimetry) in a great many experiments, and to rely upon studies of the respiration (indirect calorimetry).

The principle upon which Regnault and Reiset built their apparatus in 1850 is that upon which the modern respiration apparatus is constructed. Zuntz, long chief of the Agricultural College in Berlin, made a portable respiration apparatus to measure the energy expenditure of a man walking at sea level or on the

snow fields of Monte Rosa, subsequently used with great success by one of his pupils, Magnus-Levy, for the study of respiration in disease. This type of apparatus was brought to a much higher state of perfection in 1918 when F. G. Benedict, director of the Nutrition Laboratory of the Carnegie Institution of Washington, located in Boston, produced his portable respiration apparatus, easy to operate and inexpensive enough to be within the reach of many laboratories. This enables many students with relatively little training in physics and chemistry to have first-hand experience in determining energy expenditures from oxygen consumption and makes concrete to those interested in nutrition as an applied science the accurate scientific foundation upon which the "calorie theory" securely rests.

The Benedict portable respiration apparatus depends upon the principle that the oxygen breathed in by a subject is used in response to a need of the body and is not stored. Consequently, the oxygen consumed is a measure of the amount of combustion going on. As has already been pointed out, the amount of oxygen required to burn a gram of fat is not the same as that needed to burn a gram of carbohydrate or a gram of protein. One hundred grams of a typical fat (tripalmitin) will yield when burned 141 liters of carbon dioxide and will require from the outside for its combustion 201 liters of oxygen; 100 grams of starch will yield 83 liters of carbon dioxide and will require 83 liters of oxygen. In other words, the ratio of the oxygen consumed to the carbon dioxide given off in the case of fat is $\frac{141}{201}$ or 0.7, while in the case of starch

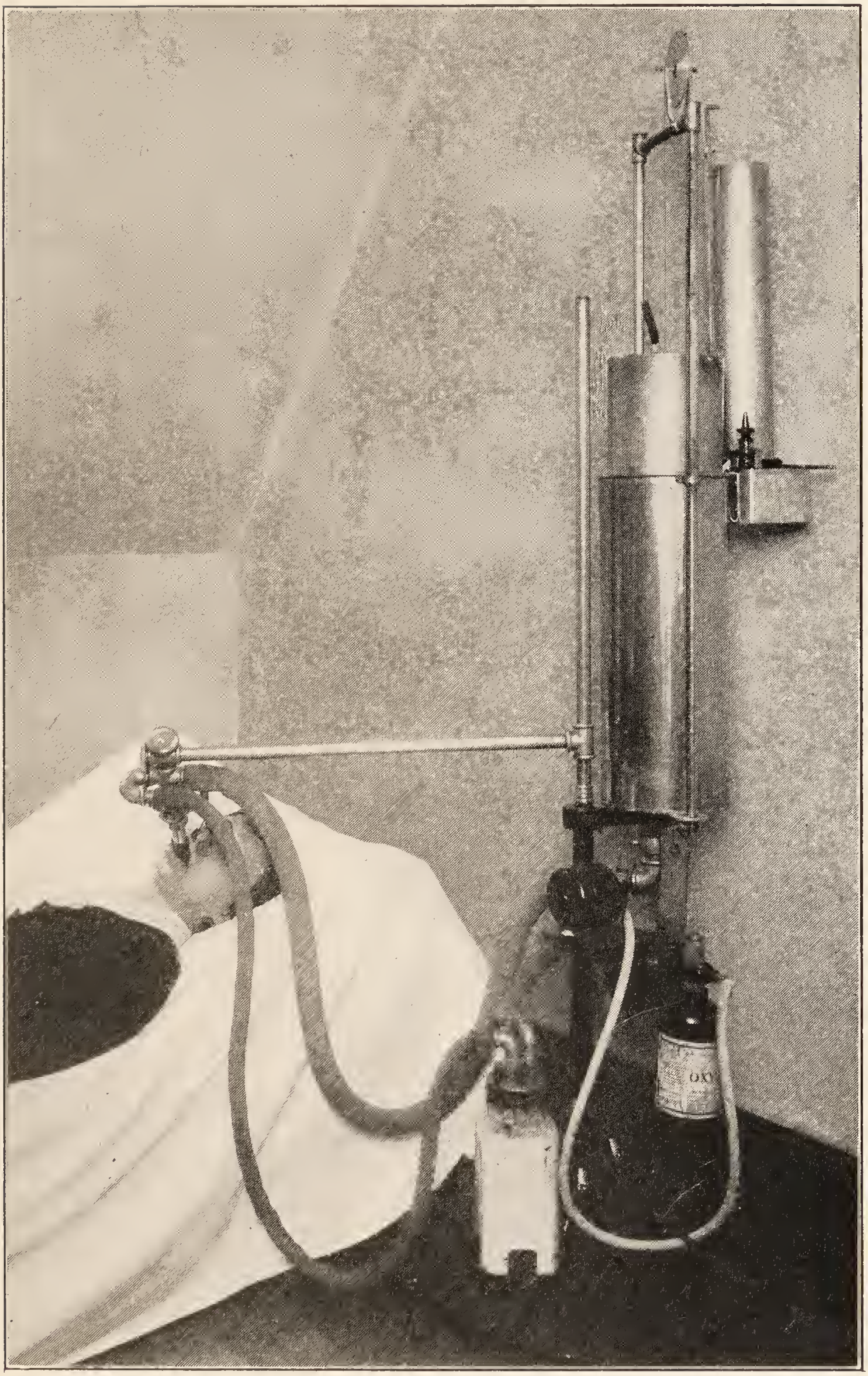


FIG. 9.—Benedict Portable Respiration Apparatus.
The subject is in position, with mouthpiece inserted and nose clip attached.

it is $\frac{83}{83}$ or 1.0. In the case of protein the ratio is about 0.8. These ratios are known as respiratory quotients. If a normal healthy person has gone from twelve to fifteen hours without food, the carbon dioxide then being excreted represents the burning of the fuel foodstuffs in such proportions as to make a respiratory quotient of 0.82. This must be assumed in using the Benedict apparatus; i. e., the oxygen consumed represents, under the experimental conditions, the burning of body fuels in the same proportions in every case. When the conditions change, recourse must be had to some type of apparatus in which both oxygen intake and carbon dioxide output can be determined and the respiratory quotient calculated exactly.

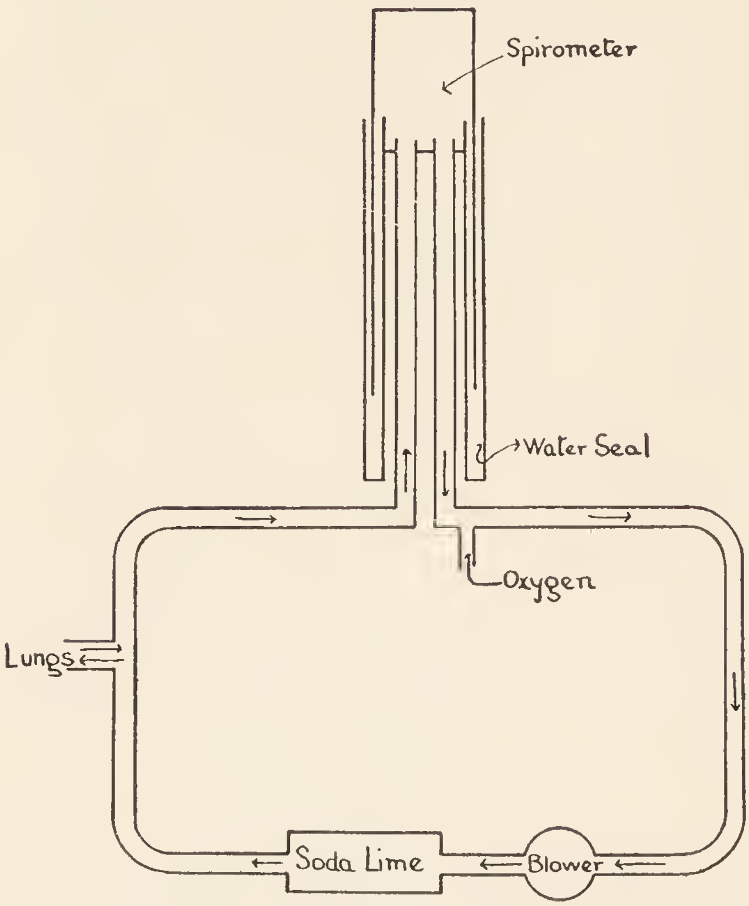


FIG. 10.—The Benedict Portable Respiration Apparatus.

By means of a mouthpiece and nose-clip as shown in Fig. 9, the lungs are made a part of a closed system, which is supplied with pure oxygen from a cylinder as required. The exhaled carbon dioxide is removed as the air circulates through a jar of soda lime. A water-sealed spirometer makes adjustments to changes in pressure due to respiration. By means of a blower the air is constantly circulated in the direction indicated by the arrows. A graduated scale attached to the spirometer makes it possible to measure the change in level of the bell as oxygen is absorbed by the subject, and thus to determine the volume in cubic centimeters of oxygen consumed.

In the Benedict portable respiration apparatus the subject is connected with the machine by means of a mouthpiece so devised as to prevent escape of air through the lips, while the circulation of air through the nose is prevented by a spring or a screw clip. The person breathes from a current of air which is kept in circulation by a blower attached to a small electric motor or by a set of valves which allow the current to go only in one direction. The air is constantly purified by the removal of carbon dioxide as it passes through a jar of soda lime. It is kept supplied with oxygen by means of a long spirometer into which, before the experimental period, oxygen is run from a storage cylinder. As the oxygen is used up in respiration the spirometer falls. A pointer attached to the spirometer indicates on a scale just how far the spirometer has fallen, and the difference between the first and the last position of the pointer indicates how much oxygen has been consumed. Corrections are made for the temperature, the atmospheric pressure, and moisture in the spirometer.

To-day, even the apparatus described above has been further simplified by the use of rubber. F. G. and C. G. Benedict have invented a "student" apparatus in which a rubber bathing cap is substituted for the metal spirometer. The bathing cap is inflated with oxygen by a small pump, until a small attached button exactly touches a given mark. As the oxygen is consumed by the subject, the button fails to touch the mark. More oxygen is pumped in to replace that used, and the number of strokes of the pump becomes a measure of the amount of oxygen used.

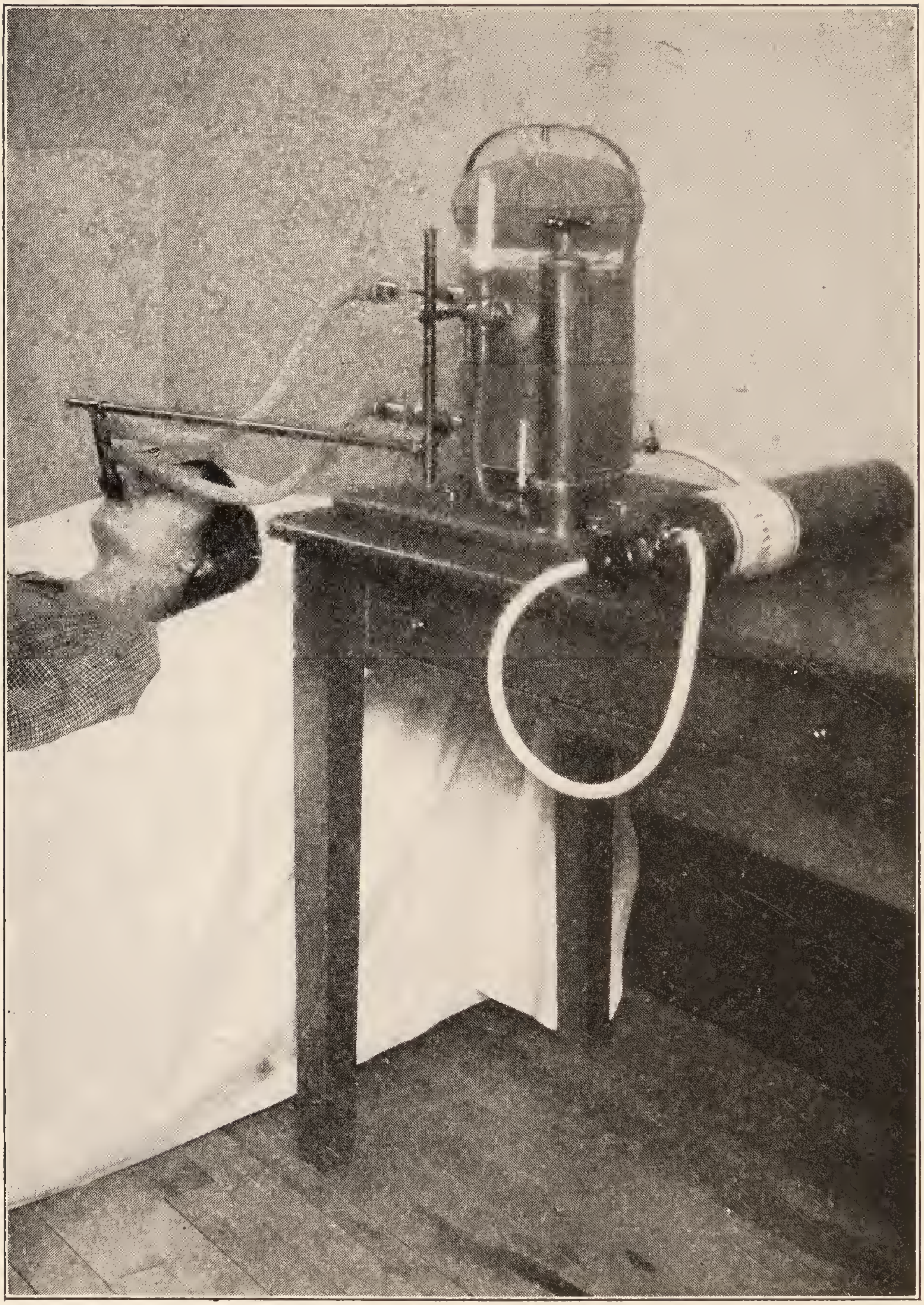


FIG. 11.—The Benedict Student Respiration Apparatus.
Subject is in position and oxygen cylinder is lying on table attached to apparatus.

In the hands of expert experimenters, results with such types of respiration apparatus agree closely with

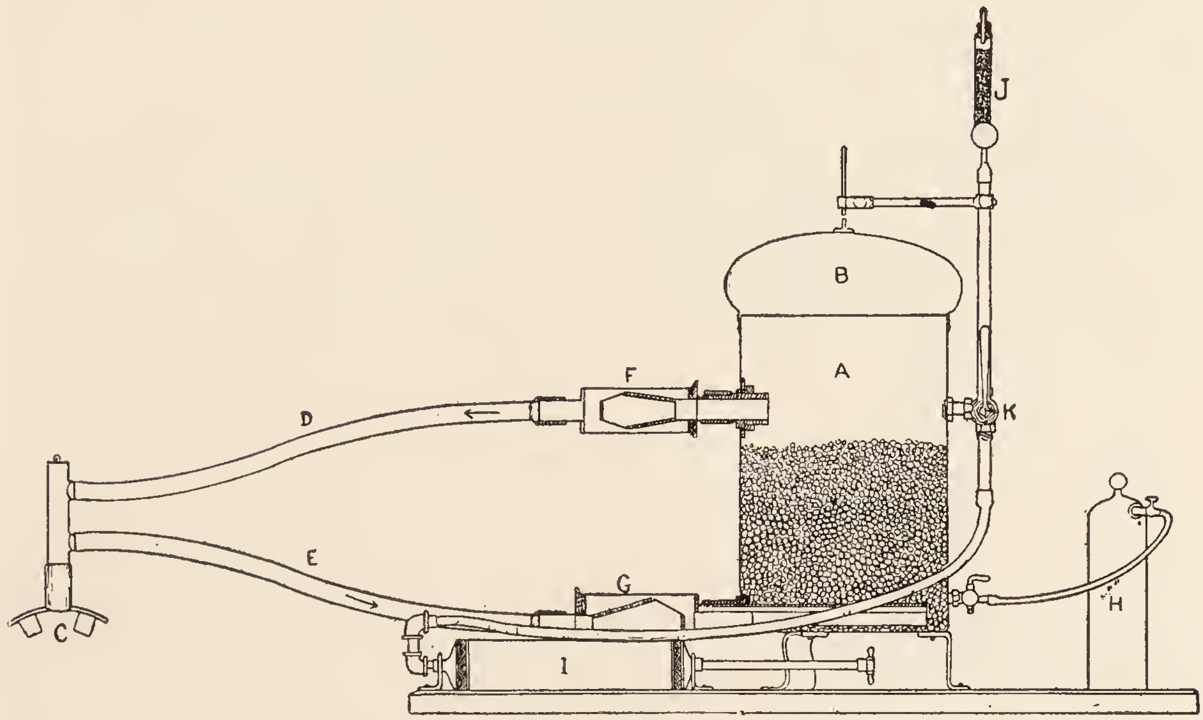


Fig. 12.—Diagram of Benedict's Student Respiration Apparatus.

A. Metal can containing soda lime to absorb carbon dioxide.
B. Bathing cap inflated so that button almost touches marker above it.
C. Rubber mouth-piece.
D and E. Rubber tubes connecting can and mouth-piece.
F and G. Valves controlling direction of air current.
H. Oxygen tank from which a supply of pure oxygen for starting an experiment is introduced into the can.
I. Pump by means of which additional air is supplied to can; it is drawn in through calcium chloride tube, J, which absorbs moisture.
K. Valve through which air from pump is admitted to can.

those obtained with the respiration calorimeter, and their use in schools and hospitals is eminently practical.

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CHAPTER II

THE BODY'S NEED FOR ENERGY AND THE SOURCE OF SUPPLY

Section I

THE BODY'S NEED FOR ENERGY

From the foregoing historical sketch, we see that animal heat is a sign of combustion (oxidation) going on within the body; and that we can find out just how much food material has to be burned to produce a given amount of heat. But why the burning?

In his attempt to get an exact balance between the carbon dioxide given off by his guinea pig and the ice melted by the guinea pig's body heat, Lavoisier was led to inquire whether or not the body used more oxygen when it was cold than when it was warm; also, whether or not more heat was generated when the animal was quiet than when it was moving about. He extended these inquiries to his work on man and found that oxidation was increased by food, by exercise, and by exposure to the influence of cold. "This kind of observation," he wrote, "suggests a comparison of forces concerning which no other report exists. One can learn, for example, how many pounds of weight-lifting correspond to the effort of one who reads aloud, or of a musician who plays a musical instrument. . . . What fatality ordains that a poor

man, who works with his arms and who is forced to employ for his subsistence all the power given to him by nature, consumes more of himself than does an idler, while the latter has less need of repair?" [1]

One hundred and fifty years of scientific investigation have only served to bring forth more evidence that in regard to its combustion the body must be thought of as a working machine. Just as in the engine every revolution of the wheel means so much fuel consumed, so in the body the lifting of the hand, the turning of the head, the bending of the knee, or the "tightening" of all the muscles under excitement means an increase in the combustion going on. But the analogy between the body and the engine breaks down when they come to a standstill. The engine then ceases to work; the body, however, does not, however hard one may try not to move a muscle. The chest and the diaphragm continue to rise and fall with every breath, the heart pumps away, 70 powerful contractions per minute, the muscles though at rest are not by any means fully relaxed; in other words, a great deal of internal work is going on even when one is in a state of apparent repose. The work a man does while sleeping for eight hours may actually equal the more obvious work of his daily vocation, if this be a sedentary one. Measurement of all this work will be considered in detail in a later section. The important point for the moment is that *life means work.* We burn our fuel to support the work which our bodies are doing. It varies in amount with circumstances but it never ceases.

[1] Lusk, Graham. "History of Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 27. D. Appleton and Co. (1922).

Section 2

FOOD AS THE SOURCE OF ENERGY

When work is to be done, fuel is demanded. This fuel must be supplied as food; in the muscles chiefly it is burned. The chemical union, in muscle cells, of the oxygen breathed in with the carbon (and hydrogen) of the food, is similar to the combustion of gasoline in the automobile engine. The chemical change liberates energy which moves the machine.

The physicist defines energy as power to do work and tells us that it exists as a force in the universe whose sum total cannot be changed. We can alter the form in which it appears and determine the place in which it shall manifest itself, but we cannot add or subtract one jot or tittle. He calls this the law of the conservation of energy. The sun is the banker of energy for the earth. Light and heat are the currency. Animals, however, cannot use these forms directly for their activities. A man cannot make a sun bath take the place of a breakfast. He must get his energy from his food. But how does the energy from the sun get into the food? Through the agency of the chlorophyll (green coloring matter) of plants. In the leaf, carbon dioxide from the air, water from the soil, and light from the sun can be bound together, making chemical compounds full of stored (potential) energy.

Let us take the corn plant as an example. Roots, stem, and leaves are chiefly woody fiber and water. The fiber will burn in a stove, yielding its stored energy as heat and light. The stem and the leaves can also

be eaten by cattle and, through long chewing and slow digestion, the stored energy of the plant fiber, or cellulose, may be released for the animals' benefit. A man, however, has no mechanism by which any considerable part of the energy of this fiber can be set free within his body; for him, it is not fuel. The seed, or kernel, is packed with starch grains. These will give heat when burned, but are too precious to use in a stove, for they will serve as fuel for men and animals. Furthermore, from the germ of the seed we can extract a fat, corn oil, which, too, would burn in a stove or a lamp, but is more useful as body fuel. Finally, from this same seed we can get another substance known as corn gluten, like the oil and starch inflammable in the ordinary sense and also combustible in the body.

From this one plant, then, we can obtain three kinds of material which will serve as sources of energy for the human machine. "It may be estimated that a 50 bushel corn crop would contain in grain and fodder nearly 10,000 therms (10,000,000 calories) of energy per acre, sufficient, if it were all converted into heat, to raise the temperature of 100 tons of water from the freezing point to the boiling point." [1] These materials burn because they all contain a considerable amount of carbon and some hydrogen, both of which are capable of uniting with oxygen. Chemically, starch is closely related to sugar, which is also available as fuel in the body. These both belong to a group of chemical substances called carbohydrates. Corn gluten belongs to another chemical group known as proteins. Car-

[1] Armsby, Henry P. *Conservation of Food Energy*, page 12. W. B. Saunders Co. (1918).

bohydrates and fats are alike in that they each yield but three chemical elements: carbon (C), hydrogen (H), and oxygen (O). The proteins yield these three, and in addition nitrogen (N) and usually one or more of the following: sulphur (S), phosphorus (P), iron (Fe). These last three have nothing directly to do with the use of protein as fuel, however. All the food fuels burn because of their carbon and hydrogen and all yield carbon dioxide and water when oxidized. We may think of the situation thus:

$$\begin{array}{c}\text{Energy of}\\ \text{sun's rays}\end{array} + \begin{array}{c}\text{Chlorophyll}\\ \text{of plants}\end{array} + \begin{array}{c}\text{Carbon dioxide}\\ \text{of air}\end{array} + \begin{array}{c}\text{Water}\\ \text{from}\\ \text{soil}\end{array} =$$

$$\text{Energy yielding materials} \begin{cases}\text{Carbohydrates}\\ \text{Fats}\\ \text{Proteins}\end{cases}$$

Just as the plant stores up in the form of these three chemical compounds, carbohydrates, fats, and proteins, the energy derived from the sun—now in roots, as the beet; now in thickened stems (tubers), as the potato; now in fruits, as the orange—so animals, eating these fuel foods in excess of their immediate needs, may store the surplus energy in their own bodies against a time of future need. Here is another point where the analogy between the body and the engine breaks down. If you pile coal upon the fire and generate more than enough steam you have to let the surplus escape; it cannot be saved for next month or next year; but if the body has a surplus of fuel it can be converted into body fat (chiefly) and stored away until actually needed. According to Armsby, a thousand-pound steer given 14 pounds of timothy hay daily will just about support

himself without gain or loss. If we want him to store up food for man we must increase his fuel supply and thus give him a surplus to store.

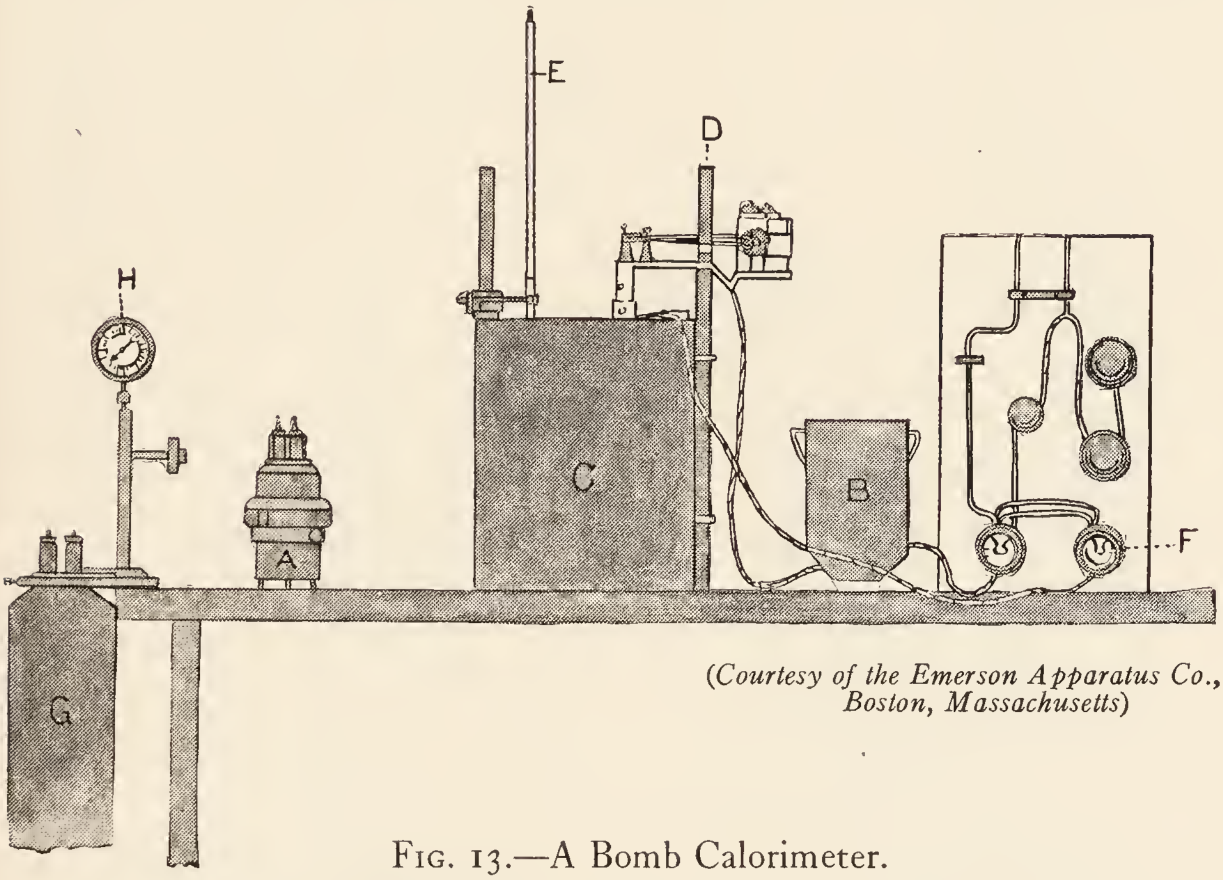
Section 3

THE MEASUREMENT OF ENERGY IN FOOD MATERIALS

We have recalled the fact that energy is a force which manifests itself in various forms: now as work, lifting a weight or pulling a load; now as heat, liberated from burning coals in the furnace; now as light, from the burning tallow of the candle; now as electricity, from the stored force of the river raging over the precipice; now as the invisible force which spans the space between chemical atoms in a molecule, and reveals itself only when they rush together in combustion, with an impact violent enough to produce vibrations which we sense as heat or light. This force can be measured in various ways: the light in terms of candle power; the heat in calories; the electricity in kilowatt hours; the work as foot-pounds or kilogram-meters. Which shall we choose as our basis for the study of foods?

Since the energy of foods is to be compared with the work which the body must do, a work unit would seem most practical. Then we might use as our starting point the amount of energy required to lift one pound of material one foot into the air. In the laboratory, however, it is much easier to convert all the potential energy of a food material into heat, and having done so, it is simpler to use a heat unit directly than to recal-

culate each time to a work unit. Furthermore, in the resting body all the energy of internal work eventuates as heat, and whenever external work is done, heat is a by-product of the activity. Hence it is customary, although the energy of food is not used directly as heat,



(*Courtesy of the Emerson Apparatus Co., Boston, Massachusetts*)

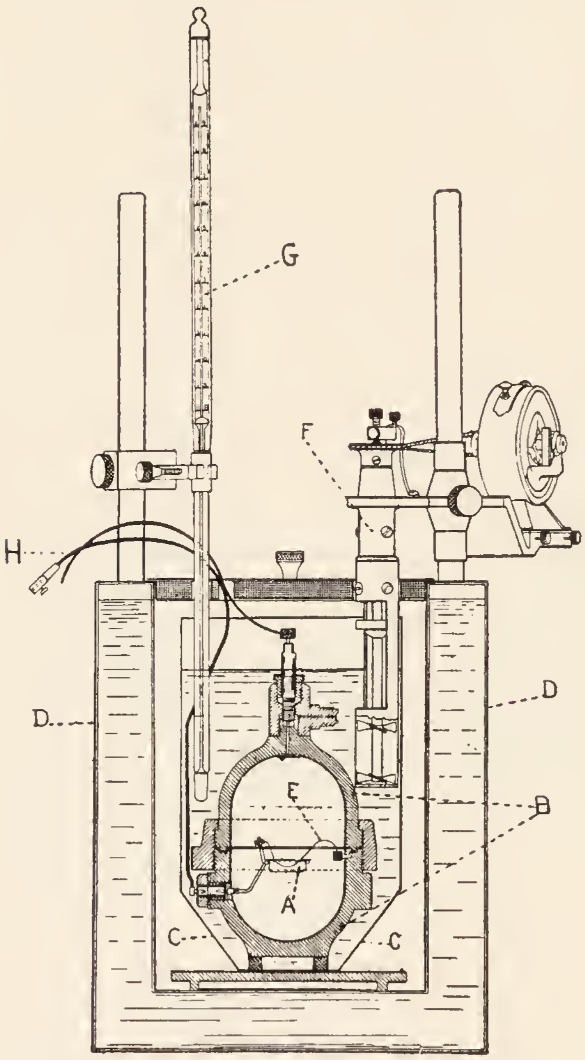
FIG. 13.—A Bomb Calorimeter.

A. Steel bomb holding sample.
B. Can containing water in which bomb (A) is placed.
C. Double-walled container in which can (B) is placed.
D. Motor-driven stirrer to agitate water.
E. Thermometer to note temperature changes in water.
F. Electrical connection for wires to bomb to ignite fuse and to stirrer.
G. Oxygen tank.
H. Gas meter to measure oxygen introduced into bomb.

to measure it by a heat unit for convenience's sake. This unit is called the calorie and it has long been in use in physical laboratories for all sorts of energy measurements.[1]

[1] The large calorie is taken as the standard for the science of nutrition.

We cannot see a calorie any more than we see the feet of gas which the meter registers or the kilowatts for which we pay when the monthly electricity bill comes in. We are bound to depend upon the meters for those measurements and, similarly, we must depend upon a special device in determining the energy values of foods. The apparatus most commonly used is called a bomb calorimeter. It consists of an inner chamber or "bomb" made of steel and lined with gold or platinum so as to be noncorrosive, into which the material to be tested is put. This chamber is filled with pure oxygen, so that combustion may be quick and complete when a tiny "fuse" of iron wire is ignited by an electric spark. The bomb is immersed in a known amount of water, and the heat generated by the burning of the food is measured by observing the change in temperature of the water.



(*Courtesy of the Emerson Apparatus Co., Boston, Massachusetts*)

Fig. 14.—Diagram of Bomb Calorimeter with Bomb in Position.

A. Platinum dish holding food sample.

B. Bomb filled with pure oxygen enclosing food sample.

C. Can holding water, in which bomb is submerged.

D. Outer double-walled insulating jacket.

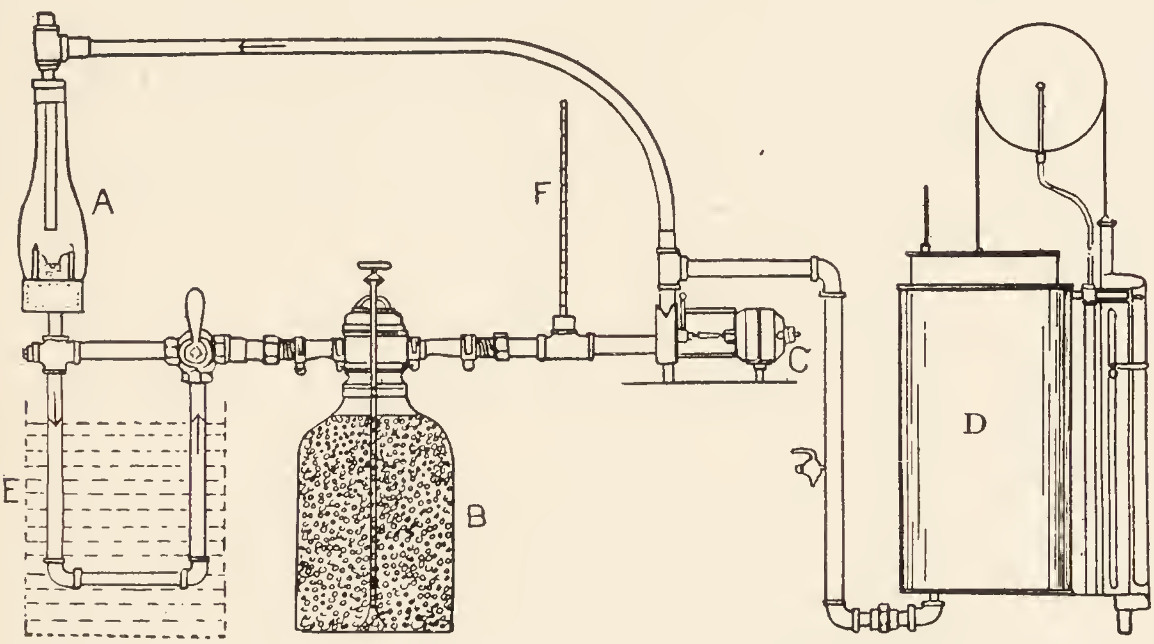
E. Fuse, which is ignited by an electric current.

F. Motor-driven water stirrer.

G. Thermometer.

H. Electric wires to send current through fuse.

Another apparatus recently devised for the same purpose is the Benedict oxy-calorimeter. In this the substance is burned in a current of nearly pure oxygen, with measurement of the volume of oxygen consumed in its complete combustion. As in the Benedict respiration apparatus described in Chapter I, oxygen is



(Courtesy of Dr. F. G. Benedict)

Fig. 15.—The Benedict Oxy-Calorimeter.

A. Combustion chamber.
B. Vessel containing soda lime to absorb carbon dioxide.
C. Blower to circulate air current.
D. Chamber (Spirometer) to measure by contraction the volume of oxygen used.
E. Pail of water and ice through which cooling tube passes.
F. Thermometer.

introduced into a closed circuit, changes in volume are indicated by a spirometer, circulation is maintained by a blower, and carbon dioxide is absorbed by soda lime. Standard factors for converting liters of oxygen into calories must be obtained by use of the bomb calorimeter.[1]

[1] For such factors as have been determined see Benedict, F. G., and Fox, E. L. *The Oxy-Calorimeter*, Industrial and Engineering Chemistry, Vol. 17, page 912 (1925).

Since foods contain sometimes one kind of fuel only, as common sugar; sometimes two, as eggs; sometimes all three, as milk; and since these will be in different combinations and different proportions, according to the food under consideration, it saves labor to have the laboratory tell us how many calories there are in a given weight of protein, fat, and carbohydrate, respectively, and then to make a few calculations ourselves, using tables of chemical composition for this purpose.[1] The physical laboratory gives us the following average values:

1 gram of pure carbohydrate, 4.1 calories
1 gram of pure fat, 9.45 calories
1 gram of pure protein, 5.65 calories

The physiological laboratory tells us that we must make certain deductions from these values because protein is never quite completely burned in the body and there is every reason to expect in case of all three foodstuffs slight losses due to incomplete absorption from the alimentary tract. The discounts proposed for an ordinary mixed diet by Atwater and Bryant after much careful study of the situation are: for carbohydrate, 2 per cent; for fat, 5 per cent; for protein, 29.2 per cent. Thus we get as final figures to use in our estimates of the fuel values of food to the body:

1 gram of pure carbohydrate, 4 calories
1 gram of pure fat, 9 calories
1 gram of pure protein, 4 calories

If we take as an example cane sugar, our problem will be very simple, since cane sugar is 100 per cent

[1] Most tables in common use are derived from data furnished by Atwater and Bryant's *Chemical Composition of American Food Materials*, Bulletin 28, Office of Experiment Stations, U. S. Department of Agriculture.

carbohydrate, and each gram will yield 4 calories; if we take olive oil, which is pure fat, each gram will yield 9 calories; and if we take dry gelatin, which is pure protein, each gram will yield 4 calories. But if we undertake to determine in this way the fuel value of milk we shall find the situation a little more complicated, for milk contains all three:

Calculation of Energy Value of One Gram of Milk

	Amount in 1 Gram	Factor	Calories
	Grams		
Protein	0.033	4	0.132
Fat	0.040	9	0.360
Carbohydrate	0.050	4	0.200
			0.692

It is evident that the above calculations can be made once for all and recorded for future reference, thus saving much unnecessary labor.[1]

Section 4

STANDARDIZING ENERGY VALUES OF FOODS FOR PRACTICAL PURPOSES

It is worth while to spend the time necessary to learn the energy values of ordinary food materials, just as it is worth while to learn the multiplication table or the order of the letters of the alphabet. One may begin with various common units in the diet, as shown in the following table:

[1] For such tables of food values see Rose's *Laboratory Handbook for Dietetics.* The Macmillan Co. (1921).

Food Material	Energy Value in Calories	
	Range	*Medium*
1 almond	10–15	12
1 apple	60–100	85
1 banana	80–120	90
1 beet	15–50	30
1 caramel	45–55	50
1 egg	65–100	75
1 onion	20–100	30
1 orange	60–100	85
1 oyster cracker	4–6	5
1 potato	90–150	100
1 shredded wheat biscuit	95–110	100
1 tomato	25–50	40

One may profitably extend such tables to include one's own customary portions of all sorts of dishes, but as individuals differ very much in regard to their habits of eating, it is not possible to make standard tables on the basis of "servings," although one may find interesting and useful tables based on the judgment of certain individuals or groups as to what constitutes a "serving." [1]

For systematic and comprehensive study of foods it is more satisfactory to adopt a standard energy unit, and the 100-calorie portion originally suggested by Irving Fisher, Professor of Economics in Yale University, has proven eminently practical. Tables are readily available giving the weights of 100-calorie portions of most common food materials.[2] With the assistance of these, and accurate scales, one may readily become familiar with the quantity of any single food material

[1] Cf. Wellman, M. T. *Food Study for High Schools*, pages 499–507. Little, Brown and Co. (1926). Also Bulletin, *Food. Why? What? How?* The American National Red Cross, Washington, D. C. (1924).

[2] Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition. The Macmillan Co. (1921).

required to yield 100 calories by simply consulting the table and weighing out the quantity indicated.

When it comes to cooked foods the matter is not quite so simple. A standard table gives the weight of 100 calories of dry rolled oats as 25 grams.[1] In cooking, water is added, more when the mush is thin and less when it is thick. The weight and measure of the cooked product will vary accordingly. By having a large number of persons trained in cookery prepare a 100-calorie portion to the best of their ability and taking the average, one arrives at fairly representative figures for both weight and measure of cooked rolled oats: measure, 1 cup; weight, 7.9 ounces.

The chances of variability in a portion of a food simply cooked with water, like oatmeal, are less than they are in the case of food mixtures for which there may be several recipes. This is illustrated very well by so simple a food mixture as cocoa, in which the amount of sugar and milk and the presence or absence of cream are the commonest variables.

Energy Value of Cocoa Prepared in Different Ways

	Cocoa I	Cocoa II	Cocoa III	Cocoa IV
	Milk, ½ cup Water, ½ cup Cocoa, 2 tsp.[2] Sugar, 2 tsp.	Milk, 1 cup Cocoa, 2 tsp. Sugar, 2 tsp.	Milk, ½ cup Water, ½ cup Cocoa, 2 tsp. Sugar, 3 tsp. Cream, 1 tbsp.[3]	Milk, 1 cup Cocoa, 2 tsp. Sugar, 3 tsp. Cream, 2 tbsp.
Calories in recipe	145	230	232	370
100-calorie portion	7 tbsp.	5 tbsp.	5 tbsp.	3¼ tbsp.

[1] 1 ounce = 28.35 grams.
[2] tsp. stands for teaspoon.
[3] tbsp. stands for tablespoon.

From the foregoing examples it is obvious that tables of 100-calorie portions of cooked food materials must be accepted with caution when not accompanied by recipes.[1]

With suitable tables at hand, it is possible to estimate with considerable accuracy the energy yield of a day's ration, as the following illustration will show:

CALORIES IN A DAY'S DIETARY ESTIMATED BY MEASURE FROM 100-CALORIE PORTIONS

Food Materials in a Day's Dietary	Measure of 100-calorie Portion	Amount Eaten Measure	Calories Consumed
Apple, baked	½ large apple	1 apple	200
Beef, roast	1 slice 5″x2½″x¼″	1½ slices	150
Bread, white	2 slices 3″x3½″x½″	6 slices	300
Butter	1 tablespoon	6 tablespoons	600
Cream, thin	¼ cup	¼ cup	100
Cream, whipped	2 tablespoons	2 tablespoons	100
Eggs	1⅓ egg	1 egg	75
Lemon jelly	½ cup	½ cup	100
Milk	⅝ cup	2 cups	320
Oatmeal	1 cup	1 cup	100
Peas, creamed	½ cup	¾ cup	150
Potato, baked	1 medium	1 large	150
Prunes	4 medium	4 medium	100
Roll	1 roll	1 roll	100
Sugar	2 tablespoons	2 tablespoons	100
Total			2,645

[1] For tables of 100-calorie portions of food consult Rose's *Feeding the Family*, 2d edition, Appendix, pages 363–378. The Macmillan Co. (1924).

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CHAPTER III

THE ENERGY REQUIREMENT OF ADULTS

In the foregoing chapter we have seen that the dream of Lavoisier has come true. We have arrived at the point where we can measure, with greater precision than the pharmacist who weighs out powerful drugs on the most delicate apothecary's scales, the amount of oxidation which is going on in the animal body under any given set of conditions. Not only because of its historical interest is it fitting to begin our study of nutrition with the energy exchange, but also because, quantitatively speaking, the greatest demand which we make upon food is that it shall supply us with calories. There are other food factors equally important qualitatively to be discussed in their turn, but in ordinary daily life few of these can be secured independently of the energy supply, while all of them may and generally must be obtained incidentally to it.

Practically, our task is to learn first how many calories we need and then to see how, by intelligent choice of foods which yield them, we may make them the carriers of every other dietary essential. This will eventually involve much study of individual foods, for, in the words of Armsby, long the distinguished director of the nutrition research laboratory at Pennsylvania State College, the problem of rationing a people "is very far from being so simple a thing as

merely supplying a certain number of calories of energy or grams of protein. Questions of palatability, of dietary habits, of market facilities, and of costs of fuel, labor, transportation, and marketing both in agricultural and manufacturing industries, all these have to be considered."[1] But we shall pursue our study of these far more successfully if we have as a foundation a clear conception of energy requirements and how they are met. In approaching the study of the energy requirement of adults, we have to bear in mind the fact that energy expenditure varies greatly with conditions of existence: it rises rapidly, for instance, when a man who has been sitting in a railroad station and has fallen asleep while waiting for his train wakens to find it pulling out, and bolts through the doorway on a dead run to catch it; it falls when an athlete who has been doing a hundred-yard dash crosses the line and sinks down to rest after his sprint. In order to systematize the factors causing such variability, we shall take as our starting point a state of energy expenditure which is practically constant from hour to hour for a given individual and is known as the basal metabolism.

Section I

THE BASAL METABOLISM

The term metabolism is used broadly for all the chemical changes which take place within the body under the influence of living cells. Some of these

[1] Armsby, H. P. *Conservation of Food Energy*, page 13. W. B. Saunders Co. (1918).

changes are concerned with the construction of body substance from materials taken from the environment as food; some with the maintenance of essentially stable tissues in an organism in which flux is the law of life; and some, as we have already seen, with the use by the body of energy-yielding materials for its internal and external activities. It is with the last of these that we are now concerned, and the general term energy metabolism is employed to designate those chemical processes which have to do with the combustion of fuel to run the human machine.

If we measure the energy expenditure of an adult each morning after he awakens but before he rises from his bed and begins to take food or to dress, we shall find in the course of a week a striking similarity in the daily returns, and we may be surprised at the amount of "internal work" which is going on. In warm-blooded animals, as Regnault observed in his pioneer investigations, the resting energy expenditure is always higher than in cold-blooded ones. The warm-blooded animal seems to live on a spendthrift plane so far as energy is concerned. This is correlated with the fact that he depends upon the heat which is a result of his internal activities for the maintenance of a uniform temperature for the body cells, despite fluctuations in the temperature of the environment. There is an irreducible minimum of energy expenditure, without which life is impossible. The absolute minimum is not reached in the waking but in the sleeping state; it is, however, more practical to take as the line of reference the energy output of the subject awake, lying quiet and confortably relaxed, twelve to four-

teen hours after the last meal. This is called the basal metabolism.

The Basal Metabolism of the Adult

The basal metabolism of a young man of average weight (154 pounds or 70 kilograms) is about 1,700 calories for the twenty-four-hour day; that of an average woman of similar age, about 1,400 calories. If we put this in terms of a few common food materials, we shall perhaps realize its significance a little better.

FOOD YIELDING CALORIES TO EQUAL AN AVERAGE MAN'S BASAL METABOLISM FOR ONE DAY

Food	Calories
Apple, 1 medium	85
Bread, 5½ ounces	400
Butter, 4 cu. in.	400
Lamb chop, 1 lean	200
Milk, 1 pint	337
Orange, 1 medium	85
Potato, 1 medium	100
Shredded wheat, 1 biscuit	100
Total	1,707

Cutting out three-fourths of the bread reduces this to the amount equivalent to the daily charge on existence for the so-called average woman (weighing 123 pounds or 56 kilograms).

To be strictly accurate, the intake and the outgo of energy will not quite balance with the eating of this food, because food itself has a stimulating effect which will raise the energy expenditure from 6 to 10 per cent; hence, to avoid drawing at all upon body reserves it will be necessary to add one or two hundred calories to the basal metabolism.

Basal Metabolism in Terms of Body Weight and Body Surface

It is often most convenient to think of the basal metabolism in terms of body weight. If Mr. Jones and Mr. Brown are both the same age, but one weighs 150 pounds (68.2 kilograms) and the other 180 pounds (82 kilograms), the total basal metabolism of the one will be about 1,637 calories and of the other about 1,968 calories. These figures do not tell us that the basal metabolism of these men is really the same, but if we divide total calories by body weight we get the same figure, 24 calories per kilogram per day.

For the young adult of average size it has been found that the basal metabolism lies very close to one calorie per kilogram per hour. At this rate, the man of average weight (70 kilograms) would have for 24 hours a basal metabolism of 1,680 calories ($1 \times 70 \times 24$).

Scientifically, a more accurate prediction of the basal metabolism can be made on the basis of the surface area of the body. This we cannot measure for ourselves, but DuBois has given us tables for determining body surface when weight and height are known.[1] These tables are derived from actual measurement of the body surface of a number of persons. The subject to be studied was dressed in close-fitting underwear, thin socks and gloves, and a section of the leg of a knitted garment made a covering for head and neck. Upon this foundation strips of manila paper were pasted to make a complete mold of the body. This

[1] A chart for this purpose is included in the Appendix.

mold was carefully removed in sections, then these were cut into pieces small enough to lie flat, and photographed on weighed paper. The imprints were cut out and weighed, and their weight compared with that of the whole sheet of paper whose area was known, thus making it easy to determine the surface area of the entire body or of any desired portion.

A normal man under 50 years of age, weighing 70 kilograms and standing 5 feet, 8 inches high, will have, according to the DuBois tables, a body surface of 1.83 square meters, and his basal metabolism will be very close to 39.7 calories per square meter per hour. His total basal metabolism for 24 hours will then amount to 1,744 calories ($39.7 \times 1.83 \times 24$). A woman weighing 56 kilograms and 5 feet, 4 inches tall, will have a body surface of 1.60 square meters and a basal metabolism of 36.9 calories per square meter per hour, making a calculated total of 1,417 calories per day.

Boothby and Sandiford [1] of the Mayo Clinic, Rochester, Minnesota, have published data on 102 normal persons between the ages of 21 and 69 years and compared their basal metabolism as actually determined with that calculated in the above fashion. They found that in over half the cases the predicted value did not fall more than 5 per cent above or below the actual value, and in only 7 cases was the deviation more than 10 per cent in either direction. Some of the reasons for these divergences from the average rate of metabolism will be discussed in the next chapter.

[1] Boothby, W. M., and Sandiford, Irene. "Summary of the Basal Metabolism Data on 8,614 Subjects with Especial Reference to the Normal Standards for the Estimation of the Basal Metabolic Rate," *Journal of Biological Chemistry*, Vol. 54, pages 791–794 (1922).

Section 2

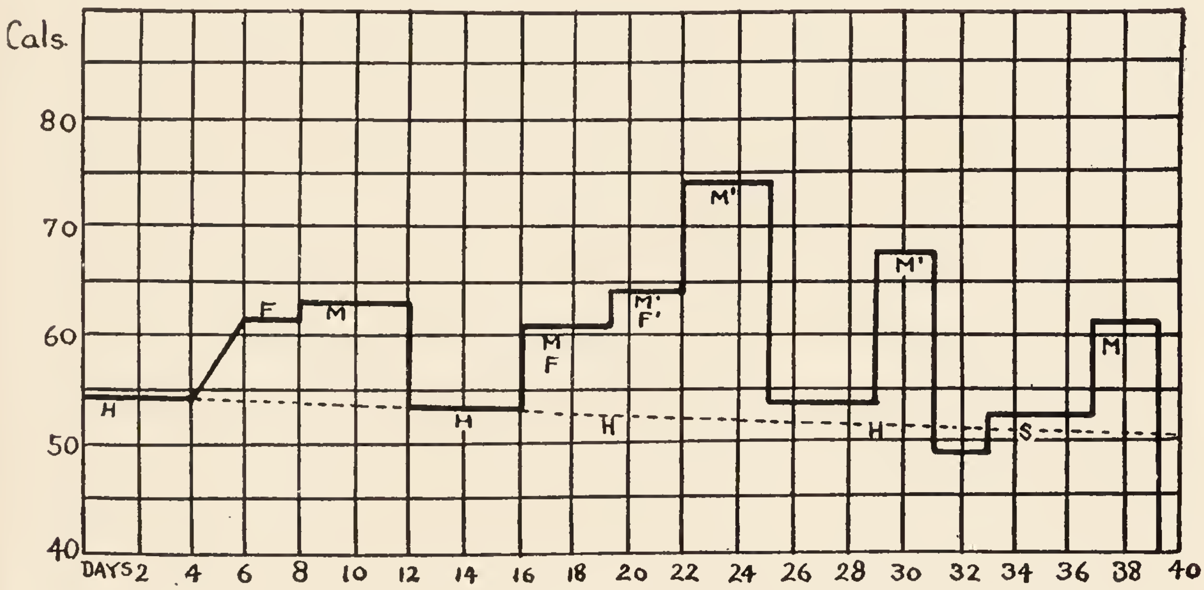
THE ALLOWANCE FOR THE INFLUENCE OF FOOD

While the basal metabolism constitutes an important and strikingly constant quota of the energy expenditure, no one could live long on the basal level. No one could remain absolutely quiet all the time, and no one could subsist without food, which itself increases the energy output. In ordinary daily life, what allowances must be made for the taking of food and for the muscular movements which are an inevitable part of existence?

Lavoisier was the first to note that eating food increased the amount of oxygen absorbed by his subject, Seguin. Sixty years later, Bidder and Schmidt gave a starving cat all the meat it would eat and found that the oxygen absorption and carbon dioxide output were doubled in consequence. Ten years after this (1862), Pettenkofer and Voit fed a dog different quantities of meat and found that the larger the meat meal the greater the combustion within the organism. They then tried fat and starch and found that the increase with fat was smaller than with starch, and neither had any such marked effect as meat. Rubner carried this investigation much farther and learned that bones, water, and meat extracts had no effect. Hence he called this stimulating effect of food, which he found to be of a different order of magnitude for protein, fat, and carbohydrate, "specific dynamic action." His chart recording the results of some of these experiments is very interesting.[1]

[1] Lusk, Graham. *Elements of the Science of Nutrition*, 3d edition, page 237. W. B. Saunders Co. (1917).

That man responds in a similar fashion, Rubner showed in another experiment, in which a man was given a calorie allowance 20 per cent above his energy expenditure without food, first of sugar and then of meat. The sugar alone raised the output 2.2 per cent



(*Archiv für Hygiene, Vol. 46, page 390, 1903*)

FIG. 16.—Rubner's Experiment showing Changes in Energy Expenditure due to Changes in the Kind of Food, Expressed in Calories per Kilogram of Body Weight.

H. Fasting metabolism.
F. Fat exclusively.
M. Meat 66% of total calories.
MF. Meat 10%, fat 90% of total calories.
M′F′. Meat 20%, fat 80% of total calories.
M′. Meat exclusively.
S. Sugar 87% of total calories.

in twenty-four hours, while the meat alone raised it more than 25 per cent, or ten times as much. Rubner came to the conclusion that if the food fed is practically all carbohydrate the rise of metabolism following its ingestion will be about 6 per cent of the total; i. e., for every 100 calories an extra 6 must be allowed for the whipping up of cell activity as this food is absorbed from the intestinal tract and begins to circulate in the

blood stream. The effect of fat is not much greater, about 14 per cent, but that of protein is very marked, amounting to 40 per cent.

We are most interested in the effect of a mixed diet, because we do not usually eat a single kind of fuel food by itself. DuBois has summarized[1] the work of investigations made in the Nutrition Laboratory of the Carnegie Institution of Washington, Boston, and in the Russell Sage Institute of Pathology, New York City. A very small breakfast (222 calories for men weighing 65 and 74 kilograms, respectively) increased the heat production 5.4 calories, or a little over 2 per cent of the total calories. A heavy breakfast (over 2,142 calories) is estimated to have increased it 111 calories (5.2 per cent), while a very heavy breakfast (3,936 calories) gave an increase of 290 calories (7.4 per cent). DuBois concludes: "It would seem safe to add an amount which equals from 5 to 6 per cent of the calories of the food in most cases where the person is on a maintenance ration" (i. e., one just covering energy requirement at rest).[2] On an ordinary mixed diet, meeting requirement for activity in addition to the maintenance requirement, it is customary to allow as much as 10 per cent of the total intake for the influence of food. This is assuming that such a diet does not consist largely of protein-rich foods.

The effect of a beefsteak by itself is strikingly shown in an experiment by Benedict and Carpenter, where approximately 9 ounces (418 calories) were eaten, with the result that the heat production was raised 138 cal-

[1] DuBois, E. F. *Basal Metabolism in Health and Disease,* page 49. Lea and Febiger (1924).

[2] Op. cit., page 50.

ories, or one-third of the total energy value of the steak. These calories were lost as heat and were not available for any useful work in the body. DuBois aptly remarks: "In this manner some of the excess food is burned and wasted just as a surtax diminishes a large income."[1]

There is one circumstance in which the "tax" may be returned to the citizen's own pocket, so to speak. On exposure to cold, there is, as we have already seen, a tendency for the metabolism to rise for the primary purpose of maintaining the normal body temperature. Now if meat be fed, the heat which is evolved during the transport to the body cells of the amino acids set free in the process of digestion of the protein can be turned to account instead of being wasted. This is quite clearly shown by a series of experiments on a dog.[2] The basal metabolism was determined at various temperatures from 7° C. (44.6° F.) to 30° C. (86.0° F.). At ordinary room temperature it was about 56 calories per kilogram; at 7° C. it was over 50 per cent higher. At ordinary room temperature, giving the dog 11 ounces of meat raised his metabolism from 56 to 76 calories, a waste of 36 per cent. When the temperature fell to 7° C., the basal metabolism rose to 86 calories per kilogram. Upon being given meat in the same amount as before, there was practically no increase in the heat production. The 20 calories which were dead loss in the first instance, when no extra heat was needed, were turned to good account in the second case, in which heat equivalent to 30 extra calories was required.

[1] DuBois, E. F. *Basal Metabolism in Health and Disease,* page 182. Lea and Febiger (1924).

[2] Lusk, Graham. *Elements of the Science of Nutrition,* 3d edition, page 234. W. B. Saunders Co. (1917).

Section 3

ALLOWANCES FOR THE INFLUENCE OF MUSCULAR ACTIVITY

A person having his basal metabolism determined finds the necessary ten minutes a long time to keep still. Ordinarily, lying still in bed means turning over now and then, bending and unbending the legs, shifting arms and hands; such "activity" may easily add 10 per cent to the basal metabolism. Sitting absolutely still in a chair, the metabolism will average 8 per cent higher than when lying down. Not long, however, will anyone sit perfectly still. If one watch his neighbors "sitting still" for a short time, listening to an address in church or in the classroom, one will find few who do not make a good many minor motions, as the following random studies show:

Movements of Adults "Sitting Still"

Person	Time	Hands to Face	Readjusting Position	Moving Hands	Moving Feet	Moving Head	Total
Woman	25 min.	0	3	6	9	28	46
Woman	25 min.	16	5	27	2	17	67
Man	25 min.	8	4	26	1	10	49
Man	25 min.	2	1	3	0	5	11

To estimate the energy expenditure involved in "sitting still," therefore, we proceed as follows:

	Calories per kg. per hr.
Basal metabolism	1.00
Muscular work—holding head and trunk in sitting posture	0.08
Slight muscular movements	0.20
Total	1.28

To this under ordinary living conditions we must add the influence of food; allowing 10 per cent of the basal metabolism, we have a total of 1.38 calories per kilogram per hour, or for a 70-kilogram man almost 100 calories per hour.

Again, if one stand upright, taking an easy pose, the energy expenditure will be raised by the muscular effort of holding the entire body erect about 20 per cent above the sitting level, or 28 per cent above the basal metabolism; if more tension be put into the muscles, as in standing "at attention," the energy output goes up still more, registering an increase of over 50 per cent above the basal metabolism.

	Calories per kg. per hr.
Basal metabolism	1.00
Muscular work—standing "at attention"	0.50
Influence of food	0.10
Total	1.60

As soon as one begins to move about, as in walking even at a very slow pace, the expenditure becomes double that of "sitting at rest," and if one walk rapidly it may rise to four, five, or six times the sitting value.

It is evident, then, that for practical purposes we need some way of expressing grades of activity, to indicate the relative severity of their demand upon the muscles. Atwater, in his experiments with the respiration calorimeter, used a stationary bicycle (ergometer) which could be adjusted to work against different degrees of electrical resistance; and with this he was able to compute the mechanical work actually done by his subjects, as well as their heat production,

oxygen consumption, and carbon dioxide output. Atwater thus describes one of his early experiments to determine the influence of work:

"In the rest experiment the subject was as quiet as he well could be. In the four days of the preliminary period he moved about but little and engaged in no considerable amount of either muscular or mental

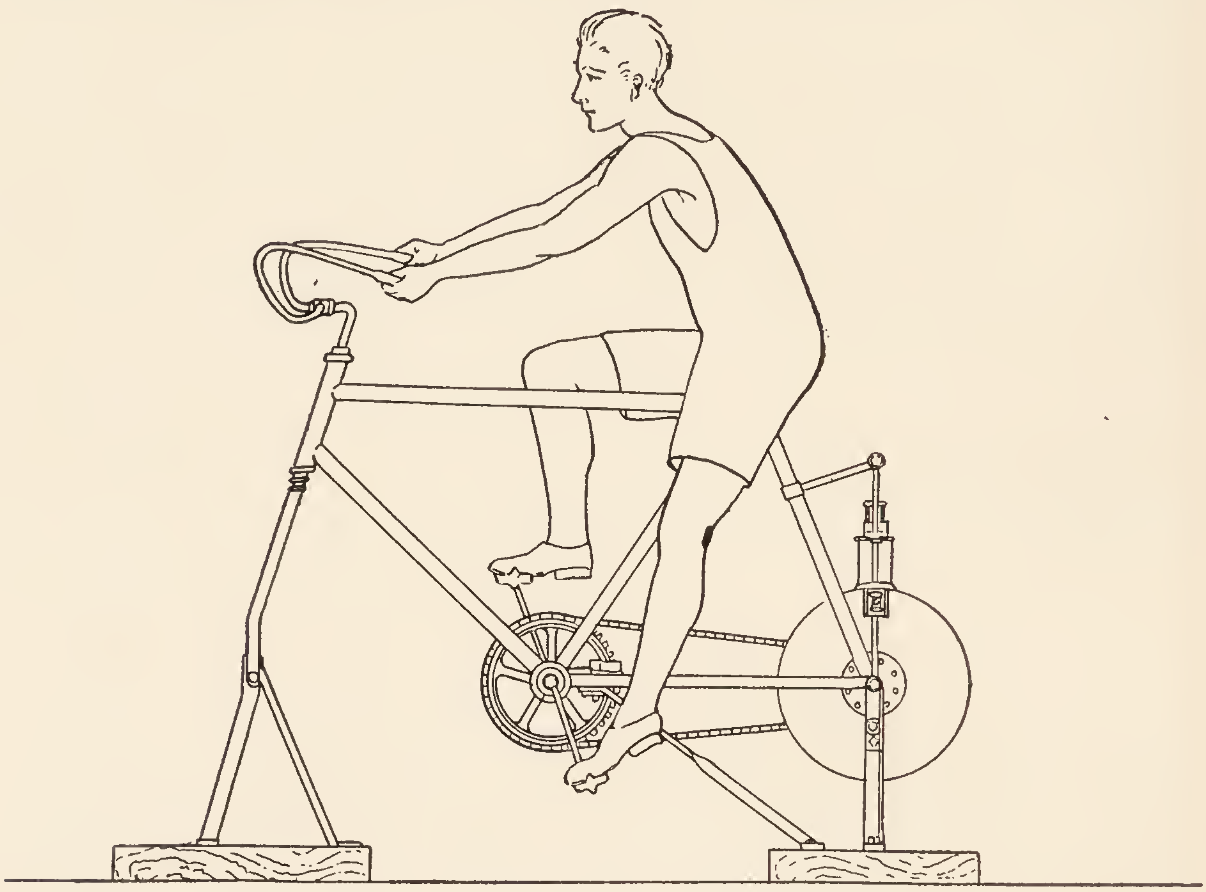


Fig. 17.—The Bicycle Ergometer.

A high-grade bicycle frame is mounted on a baseboard. In place of the rear wheel is a motorcycle hub fitted to a copper disk, and connected with this disk is an electro-magnet. To increase the amount of work done the magnetic drag upon the disk is increased. The revolutions of the pedals are counted by means of a mechanical counter attached near the pedal-wheel hub.

labor. During the four days passed in the chamber he was likewise quiet. The only muscular work done was that involved in dressing, putting up and taking down the folding chair, table, and bed, weighing himself and the absorbers, taking his meals, and caring

for the excreta. He passed a large part of the time in reading and sleeping.

"In the work experiment the subject was engaged in active muscular labor. The energy of the external muscular work done was entirely transformed into heat within the chamber. The larger part was first transformed into electrical energy by a small dynamo which was belted to the wheel of a stationary bicycle, and was then transformed into heat by an electric lamp through which the current passed. A small portion was converted into heat by the friction of this bicycle dynamo or ergometer. The heat thus produced was measured with the heat given off from the body."[1]

The following table shows the resulting figures:

	Day	Calories
Rest experiment:	1	2,348
	2	2,263
	3	2,302
	4	2,326
	Average	*2,275*
Work experiment:	1	4,060
	2	3,788
	3	3,833
	4	3,639
	Average	*3,830*
Calories representing work		1,555

With the bicycle ergometer, Benedict and Carpenter later (1917) studied the work done by a professional bicycle rider. In a "ride" of four hours and twenty-two minutes he accomplished a "century run" (or

[1] Atwater, W. O., and Rosa, E. B. *Description of a New Respiration Calorimeter and Experiments on the Conservation of Energy in the Human Body.* Office of Experiment Stations, Bulletin 63, U. S. Dept. Agriculture, page 76 (1899).

over 100 miles), expending on the average 9.75 calories per minute (585 per hour), which was two and one-half times as much as when simply sitting on the bicycle and revolving the freely-moving wheel. Another sustained effort even greater than this is recorded by Robinson, manager of the Pike's Peak Hotel and long accustomed to mountain climbing, who in two hours and thirty-one minutes ascended Pike's Peak from Manitou, 8.9 miles, the difference in altitude being 7,485 feet. His estimated energy expenditure was about 12.8 calories per minute (767 per hour).[1]

For short periods, still more amazing feats of energy transformation have been accomplished by the human engine. A study of the maximum physical power of a highly trained athlete was made by Henderson and Haggard [2] on the Yale University boat crew which won the Olympic championship at Paris in 1924. No exertion calls into play so large a proportion of the muscular tissue as rowing. The stroke, repeated thirty or more times a minute, begins "in extreme flexion of trunk and legs, with a powerful drive of the extensor muscles, the strongest chain of muscles in the body; it then passes rapidly to extreme extension, pulling throughout against the high resistance of the oar, and ends with a powerful flexion of the arms. From this position the recovery involves a rapid bending of the wrists, lowering the hands and shooting them forward, and a bending of ankles, knees, hips, waist and shoulders, with contraction of practically all the flexor muscles to these

[1] Lusk, Graham. *Elements of the Science of Nutrition*, page 431. W. B. Saunders Co. (1917).

[2] Henderson, Yandell, and Haggard, H. W. "The Maximum of Human Power and its Fuel." *American Journal of Physiology*, Vol. 72, page 264 (1925).

joints." The work was measured in three ways: (1) a racing shell with a crew with an average weight of 172 pounds was towed by a motor boat, with a spring balance attached to the launch and the towline so that the "pull" of the shell and crew could be weighed at the same time that speed was noted; (2) an oarsman "rowed" so many strokes per minute on an apparatus in which the "oar" worked a pump and forced water against a resistance; and (3) the total energy expenditure of a man on the rowing machine was determined from oxygen consumption and carbon dioxide output. The energy expended by the men, who weighed from 154 to 185 pounds, ranged from 19 to 30 calories per minute (at the rate of 1,140 to 1,800 per hour). The lower figure represents the maximum which a man can maintain for 22 minutes during a four-mile race; the higher, for about 6 minutes in races of about one and one-third miles. The energy expenditure of the oarsmen in action was thus 13 to 20 times the basal metabolism.

The foregoing are but a few striking examples of experiments to determine the energy expenditure during muscular work, in which nutrition literature abounds. The chart on page 58 shows how even changes of posture and light muscular effort quite definitely increase the energy output.[1]

In more general terms, we may grade activity as to whether it is "light," "moderate," or "severe." In such a classification it is customary to call "moderate" work which is equivalent to that of a carpenter doing a

[1] For further details as to specific kinds of activity for both men and women see Rose, M. S., *Laboratory Handbook for Dietetics*, 2d edition, pages 11–12. The Macmillan Co. (1921).

full day's labor. In this category, "very light" or "light" exercise would be that involving few muscles, as in tailoring or typewriting; "severe," that involving

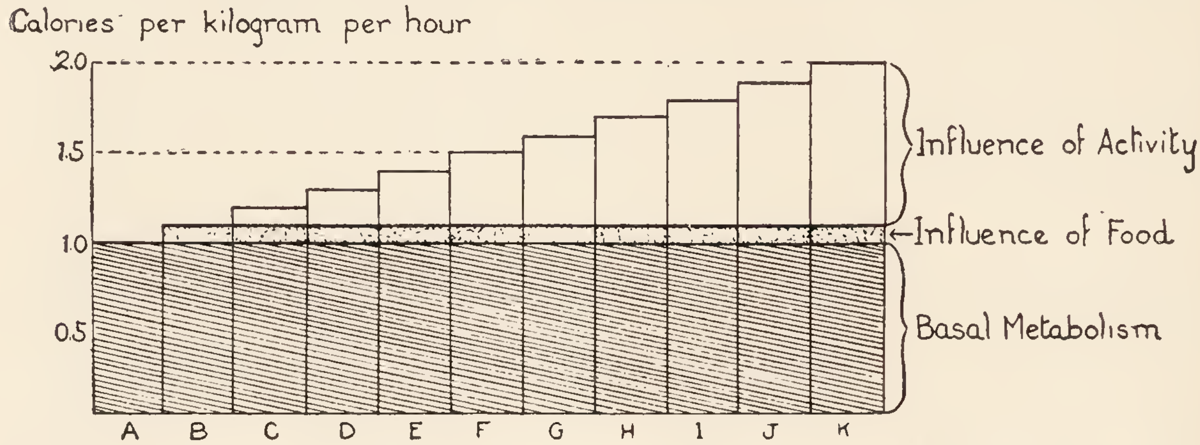


FIG. 18.—Changes in Energy Output due to Increasing Muscular Activity.

State of Activity	Calories per kilogram per hour
A. Lying absolutely still, no food taken (basal metabolism)	1.0
B. Lying absolutely still, food taken	1.1
C. Sitting absolutely still	1.2
D. Lying quietly in bed	1.3
E. Sitting at ease	1.4
F. Standing relaxed	1.5
G. Standing "at attention"	1.6
H. Singing	1.7
I. Dressing	1.8
J. Ironing with 5-pound iron	1.9
K. Walking very slowly (about 1 mile per hour)	2.0

many muscles and much effort, as in sawing wood; and "very severe" may be regarded as equivalent to running at the rate of five miles an hour.

ENERGY EXPENDITURE FOR DIFFERENT GRADES OF MUSCULAR ACTIVITY

	CALORIES PER KG. PER HR.	CALORIES PER LB. PER HR.
Sitting at rest	1.43	0.65
Very light texercise	1.93	0.88
Light exercise	2.43	1.10
Moderate exercise	4.14	1.88
Severe exercise	6.43	2.92
Very severe exercise	8.57	3.90

The Saving of Energy in Sleep

The true basal metabolism of an adult represents a condition of complete muscular repose with the brain active. What happens when the person is in complete muscular repose and at the same time asleep? One investigator so completely mastered the art of assuming at will a state of complete muscular relaxation that he found no difference between his basal and his sleeping metabolism. It is possible, however, that another person, who has achieved the greatest voluntary muscular relaxation of which he is capable, may exhibit a basal metabolism somewhat above the sleeping level because such influences as light and sound can act reflexly to increase the tonus of the muscles. This is well illustrated by Benedict's observations on Levanzin, the man who fasted in his laboratory thirty-one days. The investigator says: "A study of prolonged fasting recently carried out in this laboratory afforded an excellent opportunity for comparing the metabolism during the night when the subject was sleeping quietly in the bed calorimeter with that of the next morning when he was lying quietly upon the same bed, awake and breathing into the universal respiration apparatus. The subject slept for the greater part of the period of observation in the bed calorimeter, the graphic record of the body movements made by the self-recording bed showing that the man was remarkably quiet throughout the whole night. During the morning observation, he was phenomenally quiet, the graphic record showing a practically straight line in every experiment. According to the opinion of Dr. T. M. Carpenter, who

made the observations with the respiration apparatus, the subject had the most complete muscular relaxation and control of any of the individuals that he had ever studied." [1]

The metabolism of the subject while in the bed calorimeter during the night was compared with his metabolism immediately afterward when he was connected with the respiration apparatus in the morning, and was always higher after waking, the increases varying from 4.5 to 27 per cent.

The same investigators compared the metabolism of a number of men when lying awake in the forenoon, covered with a blanket in a cot, with that of the period from 1 A. M. to 7 A. M. when the subjects were in the same position but asleep.[2] The best three experiments showed an increase during the lying awake period amounting to about 11 per cent. Frequent observations of the pulse rate in the two conditions showed during sleep a decreased heartbeat and respiration rate, corresponding with the lower metabolic rate.

Everyone realizes that sleep is not equally profound at all times, and that during sleep there may be muscular movements which would be suppressed were one awake and having his basal metabolism determined. This tendency to slight muscular movements may well account for some of the variations in sleeping periods, even with the same subject. Furthermore, what one

[1] Benedict, F. G. "Factors Affecting Basal Metabolism." *Journal of Biological Chemistry*, Vol. 20, page 287 (1915).

[2] Benedict, F. G., and Carpenter, T. M. *Metabolism and Energy Transformations of Healthy Man During Rest.* Carnegie Institution of Washington, Publication No. 126 (1910).

has been doing previous to falling asleep may have some influence. In many of the experiments of Benedict and Carpenter with the respiration calorimeter at Wesleyan University the night periods were preceded by day periods in which the muscular activity varied greatly, and there was a tendency for the heat output to be greater on nights following work upon the bicycle ergometer than on nights following days of rest. Thus two subjects after moderate exercise and two after severe exercise showed a sleeping metabolism 7 to 8 per cent higher than their sleeping metabolism after rest, and one after severe exercise a metabolism 20 per cent higher.

For practical estimates of energy requirement, we may allow 0.93 calorie per kilogram per hour for sleeping periods, a saving of 7 per cent over the average basal metabolism.

We now have data from which we can estimate the energy requirement of a given individual with sufficient accuracy for most dietary purposes. Let us take Mr. A, a clerk in a dry-goods store, weighing 143 pounds, or 65 kilograms, with the following daily schedule:

Sleeping	8 hours
Sitting at rest	6 hours
Very light exercise (dressing, walking about store, handling goods, etc.)	8 hours
Moderate exercise (walking to and from work, and playing golf)	3 hours

We may then calculate his energy expenditure thus: [1]

[1] For a more refined estimate consult Rose, M. S. *Laboratory Handbook for Dietetics,* 2d edition, page 11. The Macmillan Co. (1921).

Estimate of a Day's Energy Expenditure

Activities	No. hours	Calories per kg. per hr.	Calories per kg. for total time
Sleeping	8	0.93	7.44
Sitting at rest	6	1.43	8.58
Very light exercise	8	1.93	15.44
Moderate exercise	3	4.14	12.42
Total per kg. for 24 hours			43.88
Total per 65 kg. for 24 hours			2,852.00

If we should make studies like the above on other men similarly employed, we should find a fairly close correspondence in the energy requirement per kilogram of body weight. Studies made by several hundred women students at Teachers College of their energy expenditure for a typical school day enable one to predict that the students with lowest activity will need about 33 calories per kilogram per day, while even the most active, being unable as students to escape a number of hours in the classroom, will seldom require more than 42 to 45 calories per kilogram. A man engaged in such vigorous exercise as sawing wood will expend twice as much per kilogram per day as a very quiet student. Extensive studies of the food consumption of people of various classes all indicate that those performing like amounts of work will have about the same average metabolism.[1] Farmers, whether American, Mexican, Italian or Finnish, require about 3,500 calories per day. For the man or the woman of average height and weight the total energy requirement for twenty-four hours will vary according to the type of occupation somewhat as follows:

[1] Cf. Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition, page 12. The Macmillan Co. (1921).

	Total Calories per Day	
	Men	Women
At rest but sitting most of day	2000–2300	1600–1800
Work chiefly done sitting	2200–2800	2000–2200
Work chiefly done standing or walking	2700–3000	2200–2500
Work developing muscular strength	3000–3500	2500–3000
Work requiring very strong muscles	4000–6000	————

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CHAPTER IV

FACTORS CAUSING VARIATION IN THE BASAL METABOLISM OF INDIVIDUALS

Section I

FACTORS DUE TO BUILD, TEMPERAMENT, AGE, AND SEX

Influence of Size and Shape

For most practical purposes we can disregard fatness or thinness in adults if we estimate basal metabolism on the basis of body surface. If, however, we make

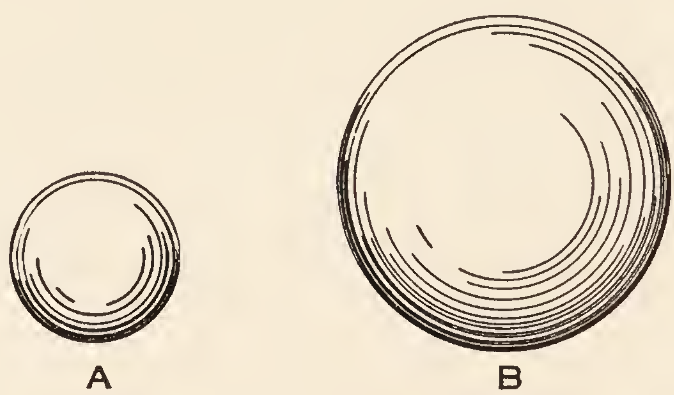
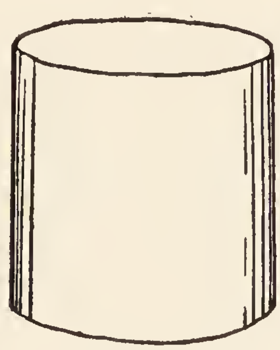


Fig. 19.—Two Balls, Showing How, Shape Being the Same, Difference in Size Affects the Amount of Surface.

	A	B
Diameter	1 inch	2 inches
Surface area	3.14 square inches	12.57 square inches
Volume	0.52 cubic inches	4.19 cubic inches
Surface to volume	6:1	3:1

calculations in terms of body weight, we shall find that we cannot apply our average of approximately one calorie per kilogram per hour without some error in

those cases in which the individual is taller, shorter, thinner, or fatter than the average. Basal metabolism being more closely correlated with surface than with weight, we must consider what effect changes in size have on the relationship between it and weight. A small body has a greater surface in proportion to mass than a large one. If we take two balls, one of them one inch in diameter and the other two inches, the first (A) will have a surface of 3.14 square inches and the other (B) of 12.57 square inches, while the volume of the first will be 0.52 cubic inches and that of the second 4.19 cubic inches. So the surface of the smaller ball in proportion to its volume is 3.14 to 0.52 or 6:1 and that of the larger ball is only 12.57 to 4.19 or 3:1. This means that if two animals alike in shape had the same relation to each other as these spheres, the smaller would produce twice as much heat per unit of weight as the larger.



A B

FIG. 20.—Two Cylinders Showing How, Weight Being the Same, Difference in Shape Affects the Amount of Surface.

	A	B
Weight	1 pound	1 pound
Diameter	2.6 inches	1.3 inches
Height	2.6 inches	12.2 inches
Surface area	31.8 square inches	48.3 square inches

In a similar manner we may inquire how the relationship between mass and surface is affected by shape. If we take a pound of modeling clay and make it into a cylinder (A) with a diameter of 2.6 inches it will have

also a height of 2.6 inches; if we take another pound and make it into a cylinder with half the diameter of A, this one (B) will have a height of 12.2 inches. While the weight is the same in both cases, the difference in shape results in a difference in surface area, the tall and slender figure having a surface exposure of 48.3 square inches, while that of the shorter figure is only 31.8 inches. In other words, the tall "thin" figure has half again as much surface area as the short "fat" one of the same weight.

If we take two men of about the same age and the same body weight but one much taller than the other and determine the basal metabolism of each for twenty-four hours, we can see how this is related to body weight and to surface in human beings.[1]

BASAL METABOLISM OF TWO MEN OF THE SAME WEIGHT BUT DIFFERENT HEIGHT

SUBJECT	AGE YRS.	HEIGHT CM.	BODY WEIGHT KGM.	SURFACE AREA SQ. M.	*Basal Metabolism for 24 hrs.*		
					Total	*Cal. per sq. m.*	*Cal. per kg.*
Mr. B.	41	183	83.1	2.06	1802	875	21.7
Mr. C.	36	169	83.0	1.89	1655	876	19.9

On the basis of body surface the metabolism is the same, but when we calculate this to calories per kilogram of body weight, the taller figure shows a metabolism higher by 9 per cent.

A similar interesting comparison may be made between individuals of the same height but differing in body weight.

[1] The data used in these illustrations are taken from Benedict, F. G. "Factors affecting Basal Metabolism." *Journal of Biological Chemistry*, Vol. 20, page 282 (1915).

Basal Metabolism of Three Men of the Same Height but Different Body Weight

Subject	Age yrs.	Height cm.	Body Weight kgm.	Surface Area sq. m.	Basal Metabolism for 24 hrs.		
					Total	Cal. per sq. m.	Cal. per kg.
Mr. C.	36	169	83.0	1.89	1655	876	19.9
Mr. E.	26	169	57.0	1.65	1531	928	26.9
Mr. W.	22	169	57.8	1.66	1472	887	25.5

Mr. C. in the accompanying table is 46 per cent heavier than Mr. E. or Mr. W. (who are almost exactly

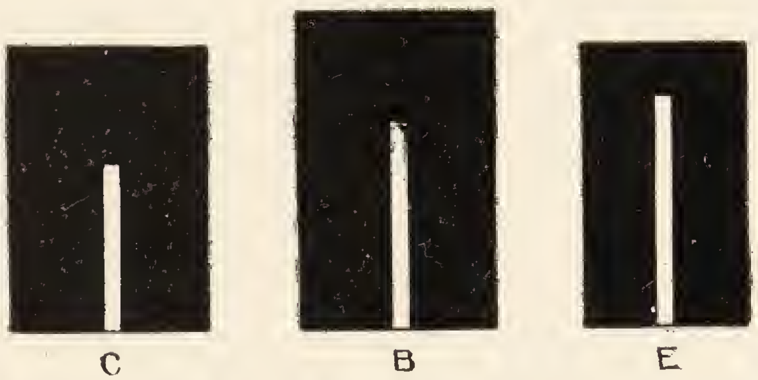


Fig. 21.—Diagram showing difference in surface area of three men of different sizes and shapes, and difference in basal metabolism due to these factors. The dark rectangles indicate body surface, the white bars, calories per kilogram of body weight.

	Mr. C.	Mr. B.	Mr. E.
Height	5 ft., 6.3 in.	6 ft., 1.2 in.	5 ft., 6.3 in.
Weight	182.6 lbs.	182.8 lbs.	125.4 lbs.
Surface area	1.89 sq. m.	2.06 sq. m.	1.65 sq. m.
Calories per square meter	876	875	928
Calories per kilogram	19.9	21.7	26.9

the same weight) and his surface area is 14 per cent greater than theirs. The metabolism per square meter of surface differs but little for the three; on the basis of calories per kilogram the metabolism of Mr. E. is almost the same as Mr. W., but both are 32 per cent higher than Mr. C.

Influence of Body Composition

Two individuals of exactly the same weight and height and consequently of the same surface area may still differ somewhat in the intensity of their basal metabolism. The explanation lies in the fact that the great seat of energy exchange is the muscle tissue, and that bone, fat, and water, while inert so far as energy metabolism is concerned, still play a part in determining weight. The large fat person not only has a size and shape favorable to an economical energy expenditure per pound of weight, but also has less muscle tissue in proportion to his bulk. Athletes, having by vigorous exercise rid themselves of surplus fat and built up firm muscle tissue, show a basal metabolism about 6 per cent higher than nonathletic individuals carefully paired with them as to size and shape. Women, with a higher proportion of body fat, have on the basis of body surface an average metabolism 7 per cent lower than that for normal men. It is often actually less than 7 per cent, as shown by the following table:[1]

Deviations of the Basal Metabolism from the Normal Average

	Age yrs.	Number of cases	Height cm.	Weight kg.	Surface area sq. m.	Deviation from normal basal per cent
Women	21–29	19	161.3	59.1	1.61	+0.9
Men	21–29	15	172.0	64.7	1.76	+4.8
Women	21–69	61	161.2	60.4	1.62	+0.3
Men	21–69	41	172.4	66.2	1.78	+1.0
Fat women		61	161.9	96.1	1.99	−0.8
Fat men		12	173.3	105.3	2.17	+0.1

[1] Data from Boothby, W. M., and Sandiford, I. *Journal of Biological Chemistry*, Vol. 54, page 783 (1922).

Influence of Muscle Tension

In making a determination of basal metabolism on any subject, every effort is made to have as complete muscular relaxation as possible. This is one reason why the basal metabolism is determined early in the morning; even under quiet conditions, tension becomes higher as the day progresses. If the person has risen from bed, dressed, perhaps traveled to the laboratory, he is required to lie quietly for a time to let the effect of exercise upon the tone of the muscles wear off. It is also important that he be in a calm frame of mind, as emotion will raise the muscle tension. If proper precautions be observed in making laboratory tests, most of the determinations on normal men will fall within 10 per cent of the average.

Influence of Mental States

As has already been pointed out, the chief seat of energy exchange is the muscles. We have seen how under the stimulus of cold they may, without our knowing anything about it, increase their tension (do more work) and give off more heat. The seat of thought is the nervous tissue. Do we increase our energy expenditure when we think?

The classic demonstration that mental activity does not materially change the metabolic rate was made by Benedict and Carpenter with the respiration calorimeter. In it twenty-two young college men took three-hour examinations and later sat the same length of time copying printed material which required no mental effort. The metabolism was only slightly greater

in the first case than in the second. No one has so far made a clean-cut demonstration of increased metabolism due to mental activity, the increases of from 8 to 10 per cent reported being probably due to small muscular movements.

Tashiro, a Japanese investigator working at the University of Chicago, has shown by an exceedingly delicate apparatus for measuring carbon dioxide excretion that when an impulse is transmitted along a nerve the carbon dioxide production may be increased to two and one-half times that of the resting nerve. If we should assume all the nervous tissue in the body to be as active as this, the total carbon dioxide output would not equal that produced by lifting one's hand to one's face. As the nervous tissue is only about 2 per cent of the total body weight, even if its metabolism increased with thinking, the total would be small, the highest estimate of the energy metabolism of the brain being only 10 per cent of the resting metabolism. Students sometimes ask, "Why do we get hungry when we study?" forgetting that they would get hungry anyway. They are generally more active in their periods of relaxation and actually need more food on holidays than on study days.

Aside from the question of the basal metabolism of the nervous system itself, mental states are, however, not without influence upon the muscles. As Stiles says, "an emotional experience is much more than a cerebral phenomenon." [1] Increased heart action, more rapid respiration, tense muscles are characteristic of

[1] Stiles, Percy G. *Nutritional Physiology*, 5th edition, page 211. W. B. Saunders Co. (1924).

more than one emotional state, and in experimental hypnosis, normal men and women have responded to suggestions inducing fear or joy with increased heat production which seems to be the direct result of the changed emotional condition. The evidence on this point is still meager and here, again, the average increase is under 10 per cent.

Influence of Internal Secretions

One of the very fascinating fields of modern physiology is that of the so-called endocrine or ductless glands, which deliver directly to the blood "internal secretions" exercising a significant influence over body processes. From these secretions various physiologically active substances have been isolated: thyroxin, from the thyroid gland; pituitin, from the hypophysis; adrenalin, from the adrenals; insulin, from the pancreas. Of these, thyroxin has the greatest effect on the energy metabolism, one milligram being sufficient to raise the heat production of a man 1 per cent, larger doses giving increases proportional to the dosage. In diseases of the thyroid characterized by abnormally increased activity there are increases in metabolism, amounting in very severe cases to as much as 75 per cent above the normal; in moderately severe, to 50 per cent. So characteristic is this rise that observation of the basal metabolism is one of the routine clinical measures in the diagnosis and treatment of diseases of the thyroid. Lowered thyroid activity also means a basal metabolism lower than normal, 20 per cent or more.

Adrenalin, from the secretion of the adrenal glands, also causes a rise in the basal metabolism for a short

time after its administration, and it has been shown that cats have a fall of about 25 per cent in metabolism after removal of the adrenals. Insulin and pituitary extracts are not definite factors in changing the basal metabolic rate, although administration of pituitary extract of the posterior lobe and pars intermedia of the hypophysis has resulted in a slight increase, averaging 5 per cent.

Influence of Age

The influence of age duirng the period of growth will be considered in Chapter V. This discussion is confined to adults. For practical purposes the metabolism of men and women between the ages of twenty and forty years may be regarded as nearly constant. Whatever change may occur is manifest only over a long period, as is evident from DuBois's suggestion that in a laboratory, for a check on the reliability of the respiration apparatus, "one or two of the normal controls who are readily available should be studied at frequent intervals throughout the year, since they should maintain a fairly constant metabolism." [1]

Harris and Benedict [2] from a statistical study of adult men and women conclude that for each year of age after twenty a man's decrease in total heat production amounts to 7.15 calories per day; i. e., if at twenty a man has a metabolism of 1,744 calories per day, at twenty-one it would be 1,737 calories; at twenty-two 1,730 calories. For a woman, the decrease is estimated

[1] DuBois, E. F. *Basal Metabolism in Health and Disease*, page 105. Lea and Febiger (1924).

[2] Harris, J. A., and Benedict, F. G. *A Biometric Study of Basal Metabolism in Man*. Carnegie Institution of Washington, Publication No. 279 (1919).

to be only 2.3 calories per day for each year of age. While this annual fall is slight, in forty years it results in an appreciable lowering of the energy expenditure. In a study of men past seventy-five years of age made by Aub and DuBois the heat production was found to be 10 to 14 per cent less per square meter of surface than the average for men between thirty and forty. They have suggested the following table to indicate the trend with increasing years.[1]

Basal Metabolism of Adults at Different Ages

Age, Years	Basal Metabolism Calories per sq. m. per hr.	
	Men	*Women*
30–40	39.5	36.5
40–50	38.5	36.0
50–60	37.5	35.0
60–70	36.5	34.0
70–80	35.5	33.0

Influence of Sex

The sex glands have secretions which account for certain sex characteristics, but no clearly defined differences in basal metabolism have been produced experimentally. Women, as has already been stated, have a basal metabolism about 7 per cent lower than that of men of corresponding age. Castrated males tend to have the higher body fat which characterizes women as a class; but there is no evidence that a total absence or diminished activity of the sex glands regularly causes a decrease in the metabolic rate.

[1] Aub, J. C., and DuBois, E. F. "The Basal Metabolism of Old Men." *Archives of Internal Medicine*, Vol. 19, page 823 (1917).

Influence of Pregnancy

A mother's gain in body weight during pregnancy totals, on the average, about 30 pounds. During the early months weight tends to remain stationary, while in the last three months gains range from 3.5 to 5.5 pounds per month. About half the gain is due to general increase in body tissue on the part of the mother herself. A detailed study of a pregnant woman made by her husband [1] showed that after the fourth month the basal metabolism rose slowly, until a few days before delivery it was about 23 per cent above what it was in the fourth month. Murlin, Professor of Nutritional Physiology in the University of Rochester, has shown that the energy metabolism of a mother and child together a few days after parturition just about equals that of the mother before confinement. He found a striking instance of this relationship between parent and offspring in two experiments with a dog that bore at one time a litter of one pup and at another a litter of five; the extra calories attributable to the lone pup were 46 (164 per kilogram) and to the five pups, 258.5 (165 per kilogram).[2] Interpreting his observations in terms of body weight, Murlin estimates that for the human mother the basal energy metabolism per kilogram per hour is only about 4 per cent higher than for the same woman before pregnancy. Hence the increase in metabolism closely parallels the increase in weight.

[1] Root, H. F., and Root, H. K. "The Basal Metabolism During Pregnancy and the Puerperium." *Archives of Internal Medicine*, Vol. 32, page 411 (1923).

[2] Murlin, J. R. "Normal Processes of Energy Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, page 622. D. Appleton and Co. (1922).

SECTION 2

THE RELATION OF TEMPERATURE REGULATION TO BASAL METABOLISM

A frog's body temperature changes as the thermometer rises or falls. On a cold day the animal is cold; on a warm day it is warm. When its body is cold, metabolism is reduced; when its body is warm, metabolism is increased. The difference between 4° C. (winter) and 30° C. (summer) may make an increase of 400 per cent in the amount of carbon dioxide produced. A man's body temperature is practically constant (close to 37° C.), regardless of the external temperature. Changes in the normal person's body temperature in the course of a day scarcely exceed one degree Fahrenheit, while in a single hour the temperature of the environment may rise or fall many degrees. In Texas, a drop of 40° F. in one hour is not uncommon; in New York in August one may step from the hot summer street into the artificially cooled theater. How do these changes in temperature affect the basal metabolism?

To get to the root of the matter, we must first rule out the influence of housing and clothing, which may greatly modify the situation. About 80 per cent of the heat usually produced in the body is lost through the skin. If we take a man's basal metabolism without clothing in a room only slightly below body temperature (30° C. or 86° F.), free from drafts or changes in humidity, there is then no thermal stimulus to metab-

olism. Atwater has shown the heat loss of a resting man to be as follows: [1]

	Calories
1. By radiation and conduction	1,683
2. By urine and feces	31
3. By evaporation from lungs and skin	548
Total	2,262

The path of heat elimination varies with the environment. There is little evaporation of water when the temperature is low; and, since there is no opportunity for loss of heat by radiation and conduction when the surrounding atmosphere has a temperature as high as or higher than the body, water evaporation must remove all the heat.

Effect of High Temperature

What happens when the temperature of the environment become equal to that of the body? If the person is free to perspire and the humidity does not interfere with the evaporation of the moisture on the skin, there will be no change in body temperature or in the rate of heat production; for as the evaporation of water cools the skin the blood beneath it will be cooled and, mingling with that from the interior of the body, will check the tendency to rising temperature. On the other hand, if we put a man into a bath at body temperature, there will be no way of getting rid of body heat—no chance for radiation, conduction, or evaporation; consequently the body temperature will rise. According to Stiles,[2] 100 calories added to the average

[1] Cited by Murlin, J. R. "Normal Processes of Energy Metabolism," Barker's *Endocrinology and Metabolism*, Vol. 3, pages 5–15. D. Appleton and Co. (1922).

[2] Stiles, Percy G. *Nutritional Physiology*, 5th edition, page 218. W. B. Saunders Co. (1924).

human body in an hour will raise its temperature nearly 4° F. It is a recognized law of physics that the velocity of chemical reactions is accelerated at a definite rate by increasing temperature, and since the reactions in living cells are chemical this law applies to them; i. e., whenever body temperature rises heat production increases in direct proportion. A bath at 42° C. (107.6° F.) has been shown to cause an increase in the oxygen consumption amounting to 15 per cent. Studying the basal metabolism under a variety of conditions in which body temperature was above normal (fevers), DuBois has calculated that the increase in energy expenditure amounts to 7.2 per cent for every degree Fahrenheit. What this means is readily seen from the following estimates on the basal metabolism of the average man:

Rise in Temperature, degrees Fahrenheit	Increase in Heat Production, Per Cent	Extra Calories Due to Elevation of Temperature
1	7.2	122
2	14.4	245
3	21.6	367
4	28.8	490

In fever, therefore, we must, as far as the nature of the disease and the condition of the patient permit, adjust the food to the body's increased demands, at the same time keeping the subject at rest to reduce energy expenditure through activity.

Effect of Temperatures Below that of the Body

If we start our study once more with a nude man resting in quiet air at 30° C. and proceed to reduce the temperature, what changes will occur in his heat pro-

duction? Perspiration begins to decrease and the peripheral blood vessels to contract so that less heat is lost. At temperatures only slightly under 30° C. there will be little change in the metabolism. As the thermometer continues to fall the feeling of "tone" develops in the muscles, meaning that the muscles, contracting more vigorously, are doing more work in order to generate more heat. How greatly the sudden stimulation of cold may affect the metabolism can easily be demonstrated by a cold shower. It has been found that at 15° C. (59° F.) a shower lasting from three and a half to five minutes more than doubled the oxygen consumption, and the metabolism thereafter falling gradually did not regain normal for an hour and a half.

This increase in response to the stimulus of cold is called "chemical regulation" of temperature, in contrast to those changes in heat loss which involve no change in metabolism and are grouped under the term "physical regulation." Chemical regulation is involuntary, but we may voluntarily increase our heat production by increased muscular work. The man waiting on the curb for a car on a cold morning stamps his feet and claps his hands; the one walking to work sets off at a brisker pace than on a balmy day. The range of physical regulation is widely extended by clothing and housing, which will be referred to later.

Effect of Body Fat on Regulation of Body Temperature

A layer of subcutaneous fat acts much like a woolen or a fur garment. Rubner studied a dog when it was thin and again after it had been fattened and found

that, while there was no difference at 22° C. (71.6° F.), there was nearly a fifth more heat produced by the dog in its thin than in its fat state if the thermometer was reduced to 15° C. (59° F.). At low temperatures, a layer of subcutaneous fat is very valuable in preventing rapid loss of body heat and saving the body from burning fuel merely to keep warm.

With rising temperatures, fat hinders heat loss and a fat man's body temperature is more likely to rise than a thin man's, because the former cannot easily dispose of heat by radiation and conduction. Therefore, the fat person is more liable to heat prostration than the thin individual and needs to be cautious about exercise, which will produce heat when getting rid of it is difficult.

Relation of Season and Climate to Temperature Regulation

Besides temperature, we must consider wind and humidity as factors in the problem of the regulation of body temperature. An imperceptible air current has been shown to increase the heat loss of the exposed area of a man's arm from 19 to 75 per cent above that in absolutely quiet air, the exact amount depending upon the temperature of the current. A young woman exposed to the windy blasts of April in England was found to have nearly doubled her resting metabolism; adult men and women exposed to an Alpine winter climate in sheltered sun-boxes showed increases in metabolism varying from 38 to 79 per cent above basal rates taken in London; and children responded with still greater increases, varying from 72 to 225 per cent.

It must be remembered, however, that when any muscular activity, such as walking, for instance, furnishes heat as a by-product there is lessened need of special "chemical regulation." While a cold plunge induces shivering (chemical regulation), a swim in the same water may leave the body glowing because the work of swimming is severe enough to result in the production of heat in excess of that needed to maintain body temperature.

Humidity facilitates heat loss when associated with low temperature and wind, but hinders it when associated with high temperature, especially if the atmosphere be quiet. The fat person suffers most from high temperature with high humidity, as what little cooling power the perspiration may have does not act as effectively through a covering of fat. In such a person, rise in body temperature easily occurs, with a resultant rise in the basal metabolism, adding further to the heat to be dissipated. Such a person works with difficulty in hot, humid weather, as each movement adds its quota of heat to the general discomfort.

Effect of Clothing and Housing

Man's triumph over every climate is due to his ingenuity in extending the realm of physical regulation through his dwelling and his garments. Even a rude hut protects from wind, wet, and heat, while a modern palace may maintain the same temperature when the thermometer outside stands at zero as when it stands at "ninety-five in the shade." Wherever there is cold, the home of civilized man is equipped with some kind of heating device, which greatly limits the work his

muscles are called upon to do to keep him warm, and in the hot season the electric fan now creates artificial wind for the cooling of multitudes.

The variety of ways in which clothing is related to a life almost devoid of shivering or sweltering are too numerous to record here. Silk, cotton, wool, fur; thick cloth or thin, woven close or woven loosely; all have a part to play. It is wonderful to think that an Arctic explorer can lie down and sleep to awaken warm and even perspiring after an Arctic night with the thermometer 60° below zero (F.) and the wind blowing a gale, provided there is not the tiniest hole in his garment. The smallest opening would be fatal as it would mean a heat loss which no chemical regulation could ever offset!

In everyday life in temperate zones, those conditions which facilitate heat loss from the body are likely to raise the metabolism unless counteracted by clothing and housing. The seashore, with a cold moist wind, is ideal for cooling the body rapidly. This is not necessarily a disadvantage, as the higher muscle tonus may be accompanied by a better appetite and the habit of eating more food become established so that it persists upon the return home after a seaside holiday. People who need to be fattened may benefit from having their basal metabolism raised by the climate, provided they can have enough food to more than meet the increased demand. When clothing is scanty and fails to conserve body heat and at the same time food cannot be found to meet the increased metabolism, the body is in danger of drawing upon its own substance for fuel. The poor suffer doubly from inadequate clothing and

shelter because their food needs are thus increased. Their thinly clad children are apt to be undernourished; whereas, the thinly clad children of the rich may benefit from this stimulus to life on a higher metabolic plane, provided they are fed intelligently.

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CHAPTER V

THE ENERGY REQUIREMENT OF CHILDREN

Beginnings in the Field of Children's Energy Metabolism

So far we have been dealing with the energy needs of the healthy adult, whose basal metabolism varies but little from day to day or year to year, and whose total energy requirement is determined chiefly by size and muscular activity. We shall now consider the span of life from birth to maturity, in which age is the greatest single factor modifying energy needs.

The aphorism of Hippocrates, "Growing bodies have the most heat; they therefore require the most food," was based on accurate observation, but any quantitative measurements of the differences between the young and the adult were not forthcoming for twenty-five centuries. Fifty years after the death of Lavoisier, two other French investigators following in his footsteps conducted the first respiration experiments on children, using a copper mask attached to the child's face and collecting the expired air in large glass globes for subsequent analysis; Andral and Gavarret in 1843 thus studied twelve children between the ages of 8 and 16 years. About thirty years later (1877) the first observations on a baby's metabolism were made by Forster of Munich, whose work was inspired by that of Pettenkofer and Voit. He used a

Pettenkofer-Voit respiration chamber just large enough to hold a child's cot and studied a number of children varying in age from 14 days to 13 years. In 1894, the first study of heat production during the initial week of life was made by Mensi of the Academy of Medicine in Turin, Italy. He placed the baby under a large glass bell in which the oxygen was replenished and measured as the infant used it up, and the carbon dioxide exhaled was absorbed and weighed.

At almost the same time (1895), at the University of Helsingfors, Sondén and Tigerstedt, who had constructed a very large respiration chamber to study the problem of ventilation of school buildings, took various groups of children between 8 and 15 years of age, sometimes boys, sometimes girls, who were induced by reading or eating apples (occasionally candy) to sit quietly for periods of four and a half hours, so that their carbon dioxide excretion might be determined. This was the first extensive study covering different ages of both sexes. A little later (1899) the first comprehensive study of the changes in the metabolism throughout the whole life cycle of the individual from childhood to old age was undertaken in Germany by Magnus-Levy and Falk. The children included 11 boys and 9 girls ranging in age from 2½ to 14 years. Although carried out nearly thirty years ago, this study was made with such skill that it is comparable with our best modern work.

In these and other experiments extending over nearly three-quarters of a century, little attention was paid to keeping the subject in absolute repose or to controlling the influence of food; nevertheless, it was clearly

established that the energy metabolism of the growing child is not only greater, weight for weight, than that of the adult, but that it varies markedly with the age of the child.

Among the outstanding studies of the next fifteen years, the most extensive is that of Benedict and Talbot, who established a respiration laboratory at the Massachusetts General Hospital and pursued with great zeal the investigation of newborn infants, their subjects finally numbering 105, varying in age from 43 minutes to 8 days.[1] They essayed to measure the basal metabolism and for this purpose used a wire crib supported at one end upon a stout spiral spring and at the other upon a knife edge, so that every movement of the child could be detected and recorded.

In 1917 the New York Association for Improving the Condition of the Poor, feeling the need in its extensive welfare work for adequate standards by which to compute the food requirement of the family, arranged for a systematic survey and digest of all the available data relating to food requirements of children. This was made by Miss Lucy Gillett, Director of Nutrition for the Association,[2] and included 563 experiments in all, covering the period from 1878 to 1917. The report of this work, available to every one, not only gives a wealth of material skillfully organized but also dietary standards of great practical value.

[1] Benedict, F. G., and Talbot, F. B. *The Gaseous Metabolism of Infants with Special Reference to its Relation to Pulse-rate and Muscular Activity.* Carnegie Institution of Washington, Publication No. 201 (1914). Also Benedict, F. G., and Talbot, F. B. *The Physiology of the New-born Infant: Character and Amount of the Katabolism.* Carnegie Institution of Washington, Publication No. 233 (1915).

[2] Gillett, Lucy. *Food Allowances for Healthy Children.* New York Association for Improving the Condition of the Poor (1917).

Benedict and Talbot transferred their respiration apparatus to the New England Home for Little Wanderers in order to study children of various ages, and in 1921 contributed a splendid survey of the basal metabolism from birth to puberty, which included, all told, 108 boys and 70 girls from birth to the age of fifteen years.[1]

Investigations with regard to the influence of puberty are still in progress and will be discussed later. It is sufficient here to note that, in spite of difficulties in studying food requirements of children which are not met in studying the adult, we can now discuss, with the satisfaction which comes from accurate experimental data, the four quotas which make up the total energy requirement of the growing child: (1) The basal metabolism; (2) The expenditure due to the influence of food; (3) The influence of muscular activity, and (4) The storage of energy-bearing materials in the process of growth.

The Basal Metabolism

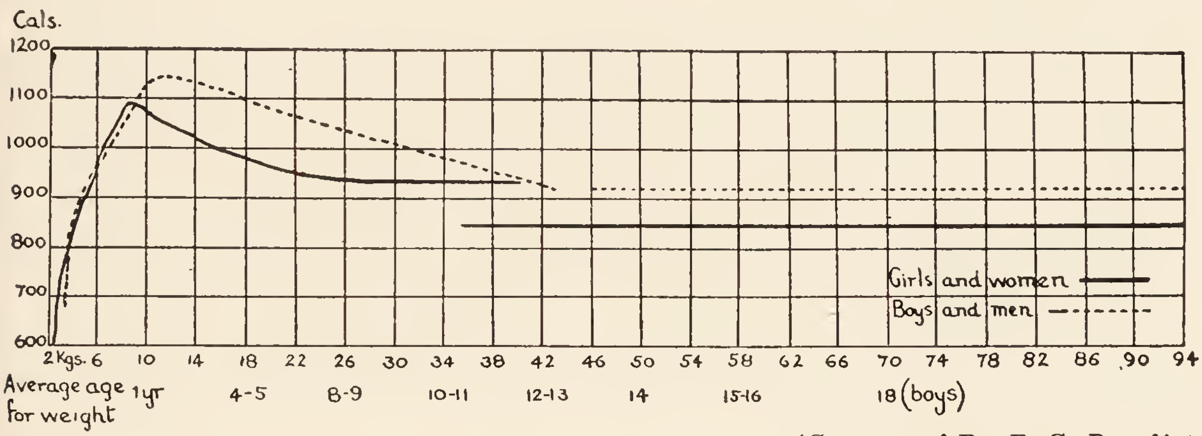
Any study of the basal metabolism of the human infant must be made during sleep and not more than three or four hours after a meal, because there is no way of keeping a baby perfectly quiet when awake or hungry. It is therefore impossible to make studies of the basal metabolism of infants on exactly the same basis as those of older children and adults. The food raises the metabolism, the sleep may lower it. Probably the actual figures obtained are somewhat higher than true basal values.

[1] Benedict, F. G., and Talbot, F. B. *Metabolism and Growth from Birth to Puberty.* Carnegie Institution of Washington, Publication No. 302 (1921).

Basal Metabolism and Surface Area

During the first week of life the baby's basal metabolism, estimated on the basis of calories per square meter of body surface, is at least one-third lower than that of the adult and very much lower than that of older infants and children, averaging 20 to 24 calories per square meter per hour. This low heat production is attributable to the low muscle tonus of the newborn. A similar condition exists in the premature infant, whose heat production is still lower.

By the end of the first two weeks the sleeping metabolism of the baby will have risen to approximately



(*Courtesy of Dr. F. G. Benedict*)

FIG. 22.—Basal Metabolism for 24 hours of Boys and Men, Girls and Women, Referred to Body Weight.

adult level, but it does not stop there; instead it keeps on rising rapidly until the end of the first year or early part of the second, when it reaches the highest point in the normal life of the individual. Thereafter, it declines, the rate varying with age until the adult level is reached, as shown in Fig. 22.

It will be observed that at first the fall is rather rapid for two or three years and then becomes more gradual. Just before puberty, in both boys and girls, there is a

period in which this decline seems temporarily arrested if there is not an actual rise for a brief period. DuBois [1] studied a group of Boy Scouts just before the onset of puberty and again two years later. The boys were given special inducements to remain as quiet as possible

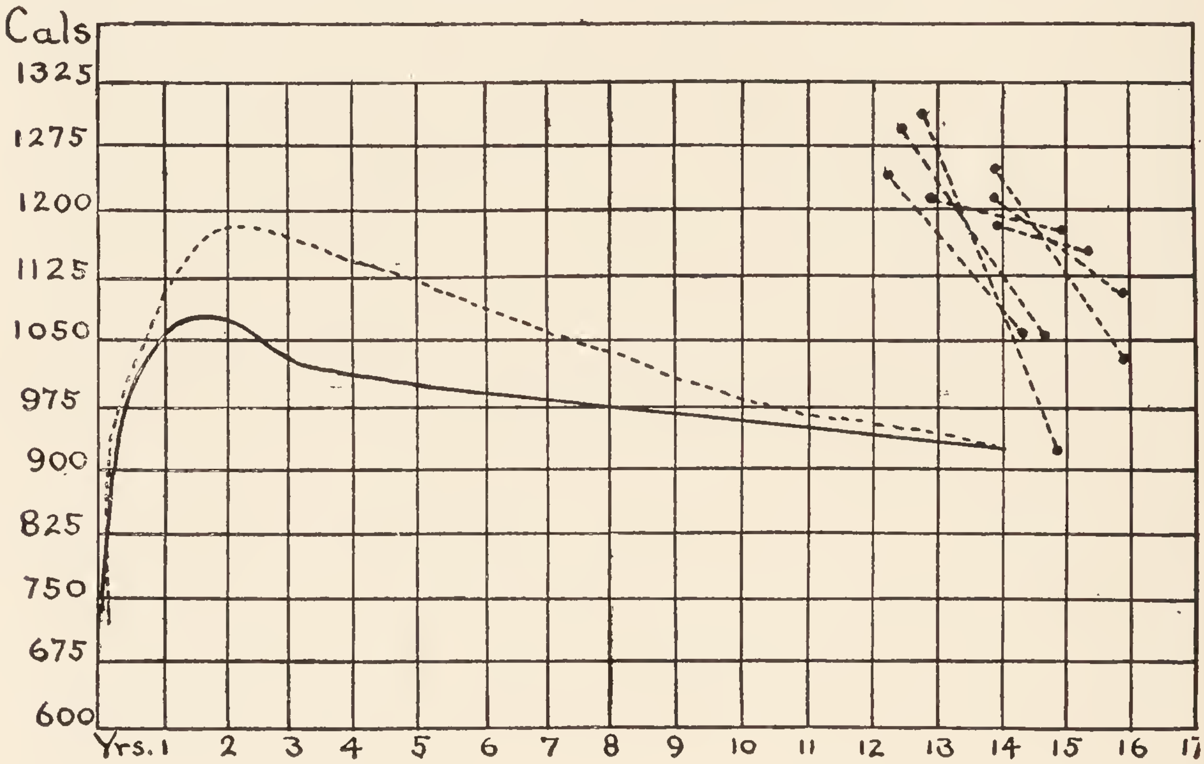


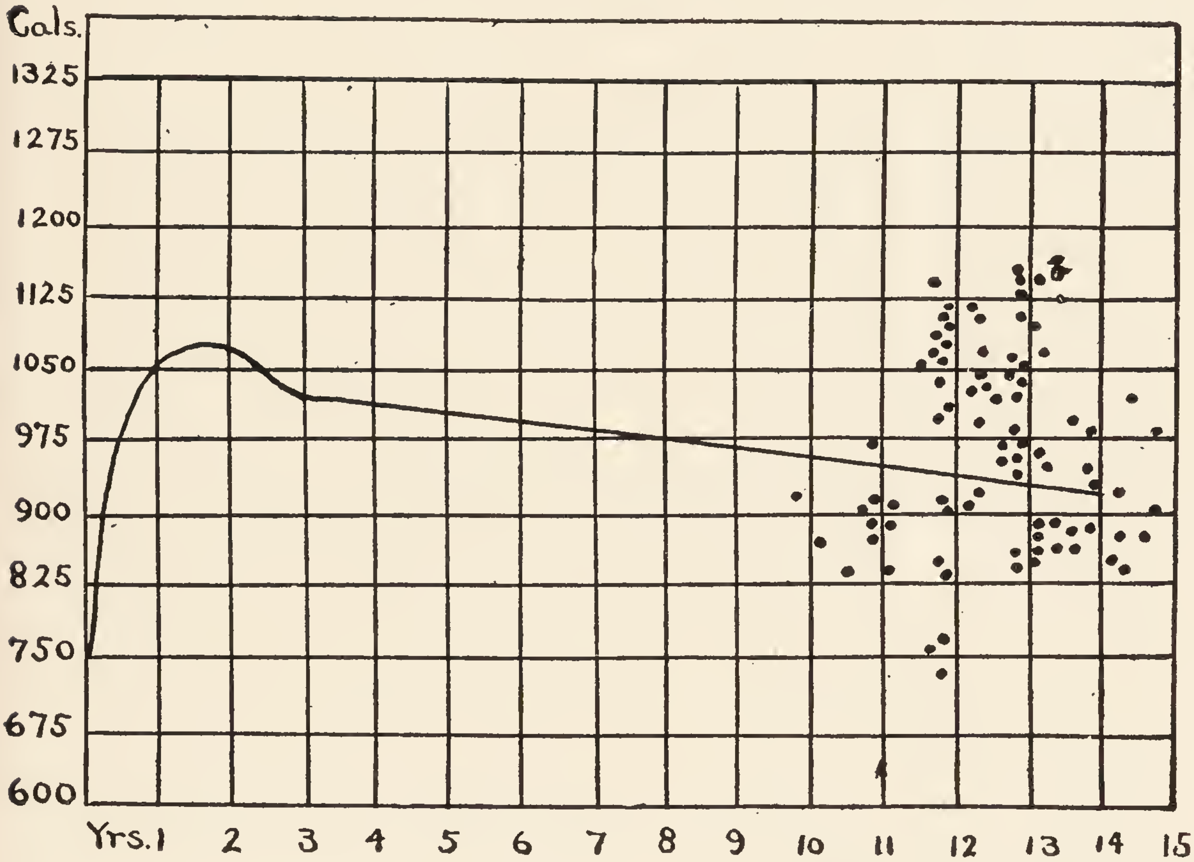
FIG. 23.—Basal metabolism of boy scouts, showing high values just before puberty, falling two years later when signs of puberty had appeared. (Data of DuBois over curve for earlier years by Benedict and Talbot.)

in the respiration calorimeter of the Russell Sage Institute of Pathology and, on the whole, were judged to be fully as quiet as adults in similar circumstances. On the first series of observations they surprised every one by a metabolism 25 per cent above the adult level. The second time, two years later, when all the boys showed signs of puberty, the basal energy expenditure had fallen in every case, as shown in the chart above.[2]

[1] DuBois, E. F. *Basal Metabolism in Health and Disease*, pages 120–123. Lea and Febiger (1924).

[2] Data from DuBois, E. F. *Basal Metabolism in Health and Disease*, pages 119–123. Lea and Febiger (1924).

Forty-three healthy girls from 12 to 14 years of age have been studied by Grace MacLeod[1] with the Benedict portable respiration apparatus and they, too, have shown a higher metabolism at 12 and 13 years of age than at 11 and 14, as indicated by the following chart.



(*Courtesy of Dr. Grace MacLeod*)

Fig. 24.—Basal metabolism of girls from 9 to 15 years of age per square meter of body surface per 24 hours, showing relationship to averages for earlier years.

Benedict and Hendry [2] were able to take groups of Girl Scouts from 12 to 17 years of age for observation in a special respiration chamber in which a dozen of them could sleep comfortably all night. Information as to muscular activity was secured by connecting

[1] MacLeod, Grace. *Studies of the Basal Energy Metabolism*, Dissertation, Columbia University (1924).

[2] Benedict, F. G. "The Basal Metabolism of Young Girls," *Boston Medical and Surgical Journal*. Vol. 188, page 127 (1921).

the springs of the beds with accurate devices for recording any movement. The girls arrived at the nutrition laboratory about 5:30 in the evening, had a simple supper at 6:00, and were entertained till bedtime by motion pictures showing the work of the laboratory. The metabolism of the group was determined

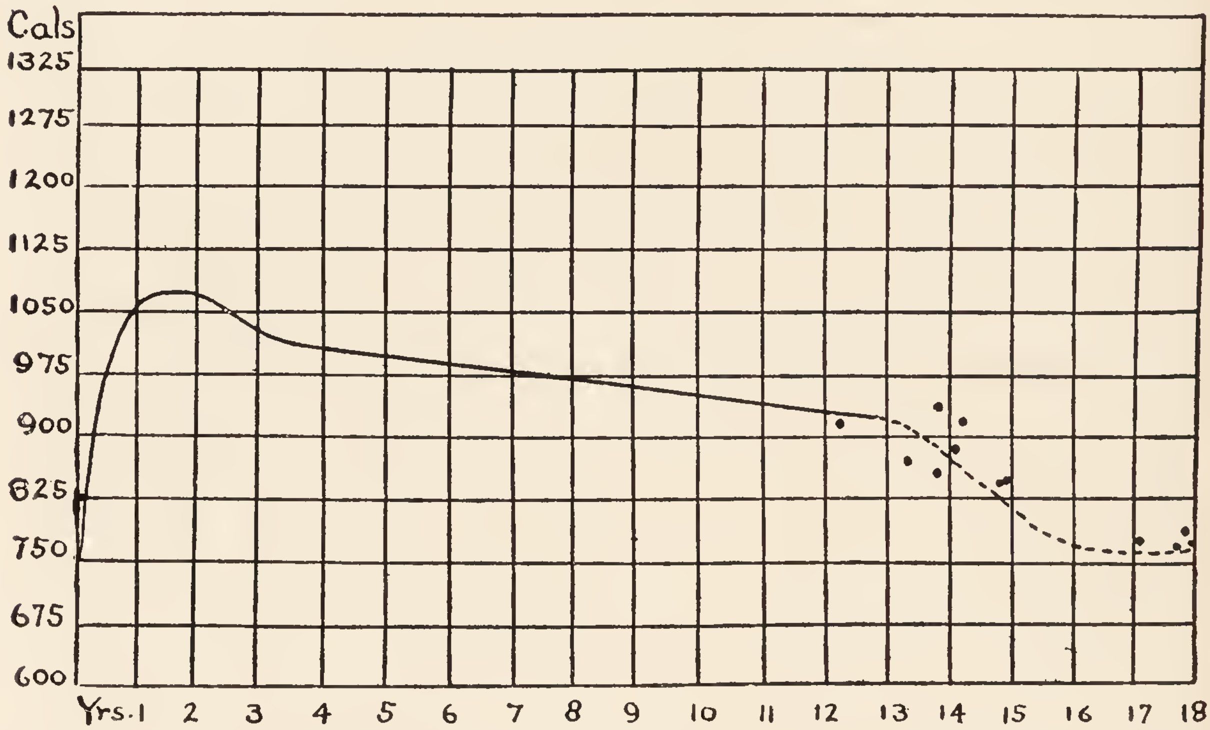


Fig. 25.—Basal metabolism of girl scouts from 12 to 18 years of age per square meter of body surface per 24 hours, showing relationship to averages for earlier years. (Benedict and Hendry.)

some time between 1:30 and 5:00 A. M. while all were sound asleep. These figures cannot be directly compared with the studies of DuBois and MacLeod because they were not made under identical conditions, but they are helpful in showing the trend from year to year.

Basal Metabolism in Relation to Body Weight

Expression of the basal metabolism in terms of surface area makes it possible to appreciate the changes in energy requirement distinctly attributable to changes

in age, but for practical everyday life, in which we measure body weight rather than surface area, it may be more helpful to have data on basal metabolism at different ages in terms of body weight. Consideration of what has already been said with regard to the relationship between size, shape, and surface area would lead us to expect that the basal metabolism of the child in terms of calories per kilogram would be greater than that of the adult. The average infant at birth has about one-seventh the surface area of the adult man, but only one-twentieth his weight. Comparison of an actual study of an infant six months old, weighing 609 kilograms and having a surface area of 0.339 square meter, with an average adult will show the difference in results when the daily energy output is calculated both to surface and to weight.

An Infant's Basal Metabolism Compared with an Adult's

	Infant calories	Adult calories
Total basal metabolism for 24 hours	312	1,700
Calories per square meter per hour	38.3	39.7
Calories per kilogram per hour	2.1	1.0

Here it appears, as already stated, that on the basis of surface this young child's metabolism is very close to that of the adult, but on the basis of body weight it is more than twice as great. As the child grows larger, the metabolism in terms of body weight as well as in terms of body surface gradually falls. Thus in a continuous study of the same little girl from the age of five months to three years and five months the following changes occurred: [1]

[1] Benedict, F. G., and Talbot, F. B. *Metabolism and Growth from Birth to Puberty.* The Carnegie Institution of Washington, Publication No. 302 (1921).

Changes in a Child's Basal Metabolism with Age

Age	Weight, Kg.	Basal Energy Expenditure		
		Total Cal. per day	Cal. per Sq. M. per hr.	Cal. per Kg. per hr.
5 mos.	5.3	317	43.4	2.5
10 mos. 1 wk.	9.2	474	42.6	2.2
1 yr. 1 mo.	11.3	564	42.8	2.1
1 yr. 5 mos.	13.4	600	40.3	1.9
1 yr. 9 mos.	15.1	633	39.5	1.8
3 yrs.	16.9	667	40.9	1.7
3 yrs. 5 mos.	17.5	660	39.2	1.6

Here the tendency of the basal metabolism to fall with increasing years, whether it is expressed in terms of surface or of weight, is clearly shown in the case of

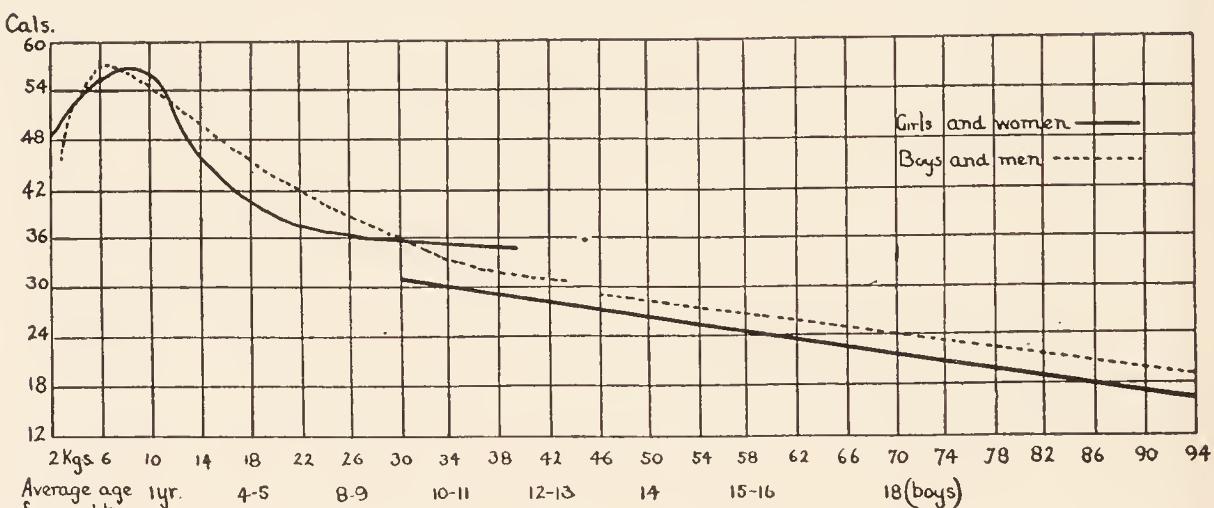


Fig. 26.—Basal Metabolism of Boys and Men, Girls and Women per Kilogram of Body Weight for 24 Hours Referred to Weight.

a single individual. Benedict and Talbot have constructed a chart based on their extensive studies which shows the characteristic changes in the basal metabolism of both boys and girls from birth to puberty, as compared with the metabolism of adult men and women.[1]

[1] Benedict, F. G. "Energy Requirements of Children from Birth to Puberty," *Boston Medical and Surgical Journal*, Vol. 181, page 137 (1919).

The following table gives typical figures in terms of calories per kilogram for basal metabolism from birth to maturity: [1]

BASAL ENERGY REQUIREMENTS OF CHILDREN IN TERMS OF BODY WEIGHT

Calories per Kilogram

AGE	BOYS	GIRLS
Birth	49	49
1 yr.	56	56
2 yrs.	56	55
3 yrs.	51	48
4 yrs.	47	44
5 yrs.	45	42
6 yrs.	43	40
7 yrs.	41	39
8 yrs.	40	38
9 yrs.	38	37
10 yrs.	37	36
11 yrs.	35	34
12 yrs.	34	32(b)
13 yrs.	40(a)	31(b)
14 yrs.	41(a)	37(b)
15 yrs.	36(a)	25
16 yrs.	?	23
17 yrs.	30	22

(a) Gillett, L. G. *Food Allowances for Healthy Children*, page 16. New York Association for Improving the Condition of the Poor (1917).

(b) MacLeod, Grace. *Studies of the Normal Basal Energy Requirement*, page 34. Dissertation, Columbia University (1924).

The Influence of Food

We have seen, in studying the energy requirements of adults, that out of every 100 calories eaten toll must be taken for the heat wasted in the process of distributing the fuel foodstuffs to the cells; a loss which varies with the nature of the diet, but is not likely

[1] Data from Benedict, F. G., and Talbot, F. B. *Metabolism and Growth from Birth to Puberty*. Carnegie Institution of Washington, Publication No. 302, pages 147 and 149, unless otherwise specified.

in ordinary life to exceed 10 per cent of the total calorie intake. We have as yet very little exact information in regard to the stimulating influence on metabolism of food during growth, but we know that food which is stored in the process does not stimulate metabolism.

The Influence of Activity

In the child, as in the adult, muscular activity increases energy expenditure in proportion to its severity. It is difficult, however, to standardize the activities of infants and children, and not enough work has been done in this field to permit definite statements as to the cost of different kinds of children's activity.

The most extensive studies have been made on babies. Benedict and Talbot have observed instances in which a baby's metabolism was raised as much as 200 per cent above the basal level by vigorous crying, but few babies can cry as hard as that. An average baby is not likely to exceed his basal output by more than 65 per cent and that only for a short time. Murlin[1] has also made many studies of the influence of activity in young babies and estimates that the extra expenditure in crying is proportional to the time spent; that is, crying 1 per cent of the time raises the metabolism 1 per cent. For an infant who cries no more than the average normal infant, he considers an allowance of 30 per cent sufficient, while for an infant crying " most of the time " 40 per cent might be allowed.

[1] Murlin, J. R., Conklin, R. E., and Marsh, M. E. "Energy Metabolism of Normal New-Born Babies, with Special Reference to the Influence of Food and of Crying," *American Journal of Diseases of Children*, Vol. 29, page 1 (1925).

Benedict and Talbot [1] studied two infants, one aged two months, three weeks and the other six months, one week, throughout the twenty-four hours and found that while they might increase the metabolism 60 or 70 per cent for short periods, the average increase for the day was about 25 per cent above basal. For older infants, not confined to the crib, an allowance of 30 to 40 per cent above basal seems to be necessary. The activities of older children have not as yet been made the subject of much investigation. Sondén and Tigerstedt's studies of groups of school children sitting in the respiration chamber (page 84) give evidence that the calorie output of boys in the schoolroom may be 75 per cent above basal, that of girls more nearly 50 per cent. What influence the activity of children in free play may have can at present only be inferred from studies of their total food consumption. When the boys in a certain private school were reported to eat 5,000 calories a day, or three times their basal metabolism, it furnished food for thought as to the influence of activity on children's energy requirement. Gillett in setting up dietary standards for children,[2] has assumed that the total food requirement would be at least double the basal metabolism.

The Influence of Growth

The proportion of the total calories ingested which will be used for growth will vary directly with the rates of growth. The charts in Section 2, Chapter XII,

[1] Benedict, F. G., and Talbot, F. B. *Metabolism and Growth from Birth to Puberty*, page 206. Carnegie Institution of Washington Publication No. 302 (1921).

[2] Gillett, L. H. *Food Allowances for Healthy Children*. New York Association for Improving the Condition of the Poor (1917).

showing the average annual rate of gain from birth to the age of eighteen years for both boys and girls will serve to make clear that the periods of greatest storage in growth occur in the first year of life and again between the ages of twelve and sixteen, the sixteenth year in boys and the thirteenth year in girls generally being the time when the rapid growth of adolescence reaches its maximum. In any one of these years from ten to fifteen pounds may be added to the body weight.[1]

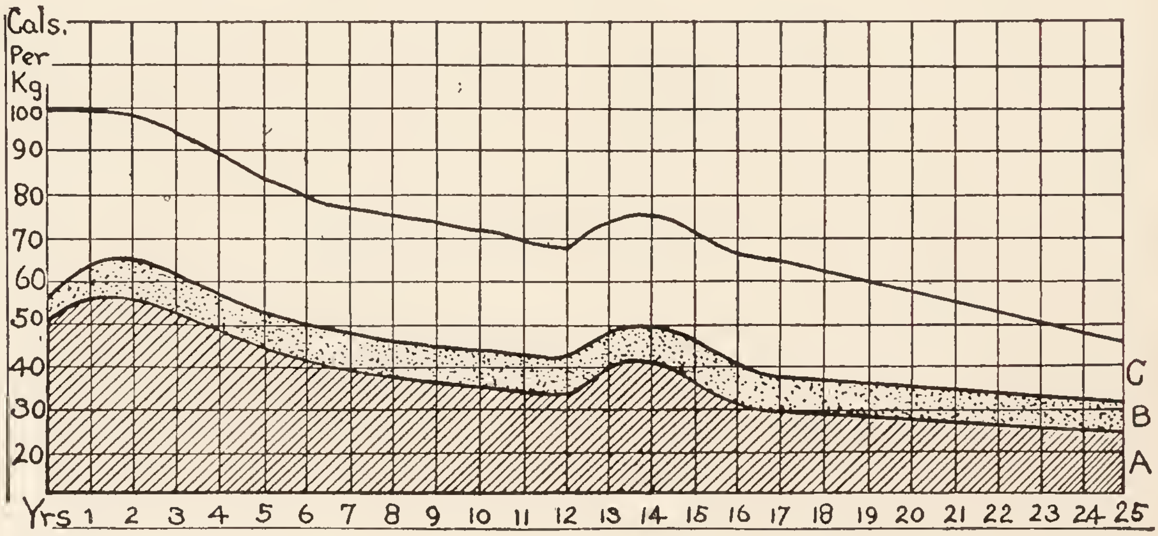


FIG. 27.—Changes in Energy Requirements of Children with Age.

A. Basal metabolism
B. Increase due to taking of food
C. Estimated allowance for activity and growth

Just how many calories are needed for growth at any given time it will always be difficult to say, since the rate of growth varies considerably with the individual; at the present time we have no standard figures for the growth quota. It must be constantly borne in mind that storage in growth is only possible when the basal energy requirement and the additional calories needed for activity have been met. If there are no calories in excess of these requirements, there can be no growth.

[1] Cf. Appendix, Tables III–VI.

Except in the periods of most rapid growth, 10 to 15 per cent of the basal metabolism probably represents the growth requirement fairly well.

The Total Energy Requirement of Children

We have now considered separately the four quotas which together constitute the total energy requirement of children, viz.,

1. Basal metabolism
2. Metabolism due to influence of food
3. Metabolism due to influence of activity
4. Storage of energy-yielding material in growth

The changes in the total daily requirement as in-

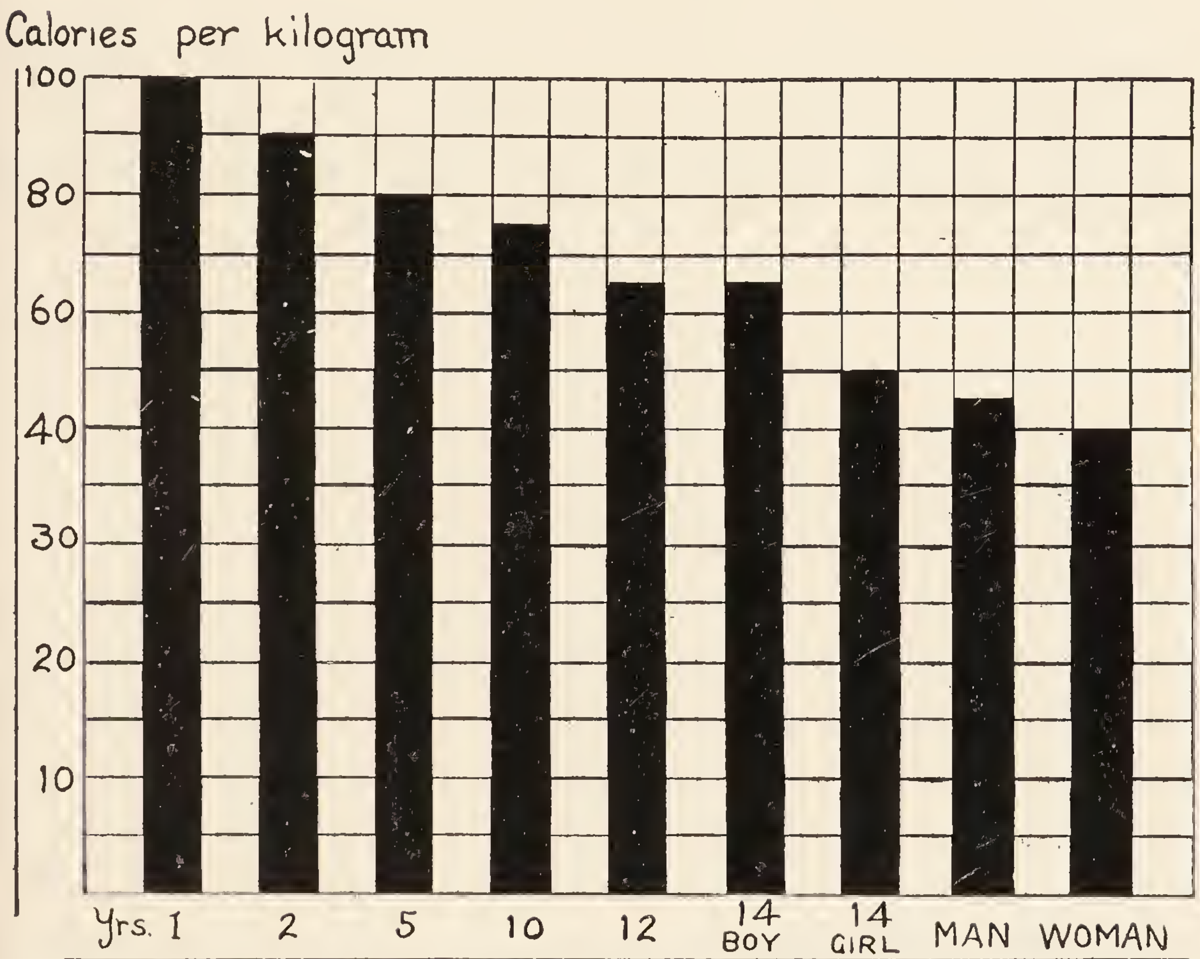


Fig. 28.—Total Daily Energy Requirement of Children Compared with a Moderately Active Man and Woman, on the Basis of Calories per Kilogram per 24 Hours.

fluenced by each of these quotas is roughly indicated in the diagram (Fig. 27).

Since basal metabolism and activity are relatively greater than in the adult and there is an additional requirement for growth, it is plain that children's total food needs will be considerably higher than those of adults in proportion to body weight. The difference between children and their parents is depicted in the chart (Fig. 28), in which the figures for the father and the mother are the averages for city dwellers.

Our most reliable information as to the total energy requirement of children has come from studies of the

TOTAL CALORIES PER DAY FOR CHILDREN OF DIFFERENT AGES

AGE, YEARS	CALORIES PER DAY	
	BOYS	GIRLS
Under 2	900–1200	900–1200
2– 3	1000–1300	980–1280
3– 4	1100–1400	1060–1360
4– 5	1200–1500	1140–1440
5– 6	1300–1600	1220–1520
6– 7	1400–1700	1300–1600
7– 8	1500–1800	1380–1680
8– 9	1600–1900	1460–1760
9–10	1700–2000	1550–1850
10–11	1900–2200	1650–1950
11–12	2100–2400	1750–2050
12–13	2300–2700	1850–2150
13–14	2500–2900	1950–2250
14–15	2600–3100	2050–2350
15–16	2700–3300	2150–2450
16–17	2700–3400	2250–2550

actual food consumption of healthy children. Gillett from her survey of 223 dietaries of healthy children eating a freely chosen diet has made the estimates

of food allowances for children as shown on preceding page.[1]

For practical use these may be expressed most conveniently in terms of body weight.[2]

TOTAL CALORIES FOR CHILDREN IN TERMS OF BODY WEIGHT

AGE, YEARS	CALORIES PER KILO	CALORIES PER LB.
Under 1	100	45
1– 2	100–90	45–40
2– 5	90–80	40–36
6– 9	80–70	36–32
10–13	75–65	34–30
14–17	65–50	30–23
18–25	5 –40	25–18

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[1] Gillett, L. H. *Food Allowances for Healthy Children*, page 8. New York Association for Improving the Condition of the Poor (1917).

[2] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 223. The Macmillan Co. (1926).

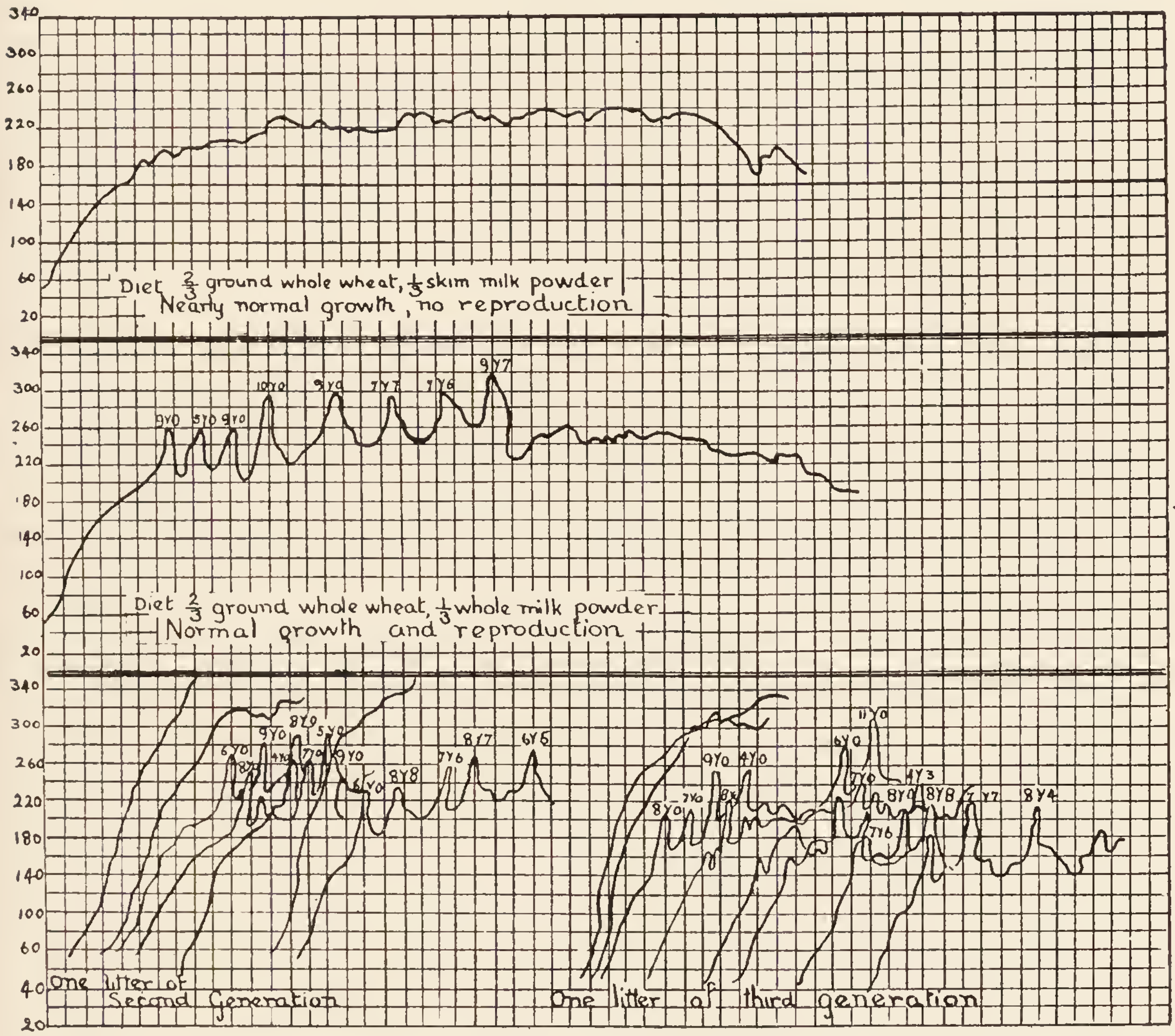
CHAPTER VI

SHORTAGE AND SURPLUS OF CALORIES

The problems of nutrition in the human race at the present time are not primarily problems of keeping alive. Only famines cause the death of any large number from dietary restrictions, and consideration of the way in which great populations like those of India and China have adjusted themselves to rations far from what we now regard as ideal shows enormous capacity for adaptation so far as diet is concerned. We must not, however, consider a diet ideal when it merely maintains life. The best method of demonstrating the difference between a maintenance diet and an optimum one for the individual and the race is by means of experimental animals in nutrition laboratories.

For instance, it is possible for a rat to grow to full adult size and produce offspring which survive and in turn reproduce on a diet consisting of one-sixth dried whole milk powder and about five-sixths ground whole wheat, plus a little common salt. The adults in the first generation of rat families so nourished appear to the casual observer quite like those of another family, nourished on a diet in which the proportions are different, viz., one-third whole milk powder and two-thirds whole wheat. Only by keeping account of the number of animals born to each mother, the age of maturity, the life span, the rate of growth, and the maximum rate of

each individual is any difference in the quality of the two diets detected. The following graph shows the growth of two families whose diet differed only in that one had a liberal amount of whole milk while the other



(*Courtesy of Drs. H. C. Sherman and Florence MacLeod*)

FIG. 29.—Experiments showing how two diets, each capable of bringing well-born young to maturity may not be optimum when tested for their value in reproduction and lactation. The first growth curve is the record for over two years of a female rat on a diet of dried skim milk and ground whole wheat. The second shows her twin sister, on a diet in which the skim milk powder was replaced by whole milk powder. The lowest set of curves shows one litter of her descendants in the second generation and one litter in the third generation. Similar records may be pictured for her through 16 generations.

had skim milk instead. The family on one-third whole milk powder was still prospering in the sixteenth

generation; the one on the skim milk diet had no descendants whatsoever.[1]

The Sources of Body Fat

The normal human body has firm, elastic muscles and a moderate store of fat widely distributed over the body, under the skin, around the visceral organs, among the muscle fibers and elsewhere. This fat is advantageous as an insulator, saving the combustion of fuel for the production of heat under the stimulus of cold; it also serves as padding for the viscera and the muscles, protecting against jars and blows; most significant of all, it acts as a storehouse of energy upon which the body can draw when for any reason food is not immediately forthcoming. We burn our fuel foods according to the demand of the muscles for energy, not according to the amount eaten. Whatever is eaten in excess of immediate need is stored for future use. Carbohydrate foods (sugar and starch) are stored as glycogen in the liver and to some extent in the muscles; however, the body's capacity to store glycogen being limited, when the glycogen storehouses are full the incoming carbohydrates, if not immediately needed, will be packed away in the still more concentrated form of fat. Fat eaten as such is also stored in the body practically unaltered if not required as fuel at once. Protein, if eaten in large quantity, tends to burn itself off on account of its stimulating effect upon combustion. The well-nourished body carries some reserve protein, but has no capacity

[1] Sherman, H. C., and Smith, S. L. *The Vitamins*, page 197. The Chemical Catalog Co., Inc. (1922).

for storage of any large surplus. In this respect protein differs markedly from carbohydrate and fat.

When a person begins to fast, the reserve glycogen is burned first and is ordinarily exhausted in a day or two. Then fat is drawn upon along with some protein, and the length of time the person can fast without harm is practically determined by his fat reserves.

Section 1

SHORTAGE OF CALORIES

Vigorous human beings carry some reserve of body fat. The best information we have as to the relationship between body weight and health is derived from the data of life insurance companies. These give us the body weight for age and height which has most frequently been found associated with health and longevity. Upon the adult who deviates much in either direction from the so-called normal average rests the burden of proof as to whether or not he is as well nourished as he ought to be. The ideal way to settle the matter is to have a complete physical examination. Schools and colleges are increasingly attentive to the desirability of such examinations for students and provide for them through their medical or other health services, while more and more other health agencies are making such examinations possible for the citizens at large. Any adult can, however, determine by comparison of his own weight with standard weight tables[1]

[1] For such tables, see Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition pages 9 and 10. The Macmillan Co. (1922).

whether he is below average weight for age and height and, if so, how much. The best weight for an adult over thirty is now adjudged to be his normal weight for age thirty. Deviations of 15 per cent or less from this in either direction may or may not be significant, but it is advisable to seek the explanation for the deviation, in whichever direction it occurs, and to consider its effect on health and efficiency.

Undernutrition in Adults

It is not desirable for adults to carry too great a store of reserve fuel, as it may become a handicap instead of an advantage. On the other hand, it is possible for the adult to become habituated to living on too low a nutritional level, so that he is unconscious of any disadvantage and will protest that he is "perfectly well," while as a matter of fact he is more liable to both physical and mental fatigue, to nervous diseases, to tuberculosis and other infections, than if he were living on a higher nutritional plane. This is corroborated by investigations made by Blunt and Bauer at the University of Chicago [1] in regard to the basal metabolism and food habits of nineteen underweight college women; eleven of these were found to be eating less than 500 calories a day in excess of their basal metabolism. They confessed that they became tired very easily and yet they were quite certain they were eating enough and could not possibly eat any more. When one of them, who weighed only three-fourths as

[1] Blunt, Katharine, and Bauer, Virginia. "The Basal Metabolism and Food Consumption of Underweight College Women," *Journal of Home Economics*, Vol. 14, pages 171 and 226 (1922).

much as she should, was finally induced to increase her food consumption, she admitted that it was very astonishing how much more she could eat and how much better she felt. Very often women even less severely underweight than this one suffer from chronic fatigue to which they have become so accustomed that they are utterly unaware of how much better they might feel. The combination of a long night's sleep and an increased food intake will often increase vitality surprisingly.

Further evidence of the effect of living on a low nutritional level is furnished by the study made by Benedict and some of his associates [1] on a squad of twelve young men whose habit before the experiment was to consume from 3,200 to 3,600 calories daily. For the first three weeks they were limited to 1,400 calories a day, with a consequent fall in body weight amounting to 12 per cent of their original weight. They were then able to maintain this reduced weight on 1,950 calories daily, and by numerous tests gave evidence that their efficiency in work of various sorts was not measurably impaired. However, they said that they felt less energetic, and had to drive themselves to their tasks instead of undertaking them with abounding energy and a surplus of good spirits. In gymnasium tests they gave out sooner than when living on the higher nutritional level and took less pleasure in their performances. This is in harmony with other studies of undernutrition, which show in various ways that the body tends to conserve its forces

[1] Benedict, F. G. *Human Vitality and Efficiency under Prolonged Restricted Diet.* Carnegie Institution of Washington, Publication No. 280 (1919).

when food supplies are insufficient, both by a lowered basal metabolism and by physical inertia.

Undernutrition in Children

Undernutrition in children is more serious than in adults, because it interferes with the normal development of the body. It is more difficult for the child to accumulate reserves because of his high energy expenditure. He must eat steadily, day by day, his full quota if he is to grow properly. Standards by which to determine normal nutrition of children at various age levels are still under investigation, and no method devised for determining nutritional state from height, weight, and age can be used without regard to other signs of health and vigor. Nevertheless, the tables of Woodbury and of Baldwin and Wood,[1] worked out by the study of thousands of American children, are a very great help in determining what the probabilities are. There is little doubt that a child 15 per cent underweight for age and height according to these tables is in need of nutritional care and the chances are that a child 10 per cent underweight is not in his best physical state.

The number of children given annual physical examinations is rapidly increasing and it is to be hoped the time will soon come when a child can be tested periodically from birth until he is able to assume responsibility for securing his own health examinations. That 30 per cent or more of our American school children should be estimated to be undernourished is a warning as to ignorance and carelessness. While some of the underweight children are baffling problems, the

[1] Appendix Tables, III–VI.

majority of them yield to a hygienic mode of life, including an adequate diet; the others should be under the care of physicians, either privately or at child welfare stations, so that the fundamental causes of their physical inadequacy may be skillfully investigated and as far as possible removed.

The Causes of Undernutrition

Ordinarily we depend largely upon appetite as a guide to food consumption, but seldom is this adequate without intelligence to direct it and check the results of following its dictates. Just as an extra pat or two of butter stored every day for ten years may transform a 150-pound man into a case of obesity, so a consistent shortage of calories may result in undernutrition. This deficit may be unsuspected if the person follows his routine of three meals a day. As Morgulis has aptly remarked in his treatise on undernutrition: "A person, engaged in the performance of heavy work on a dietary allowance which supplies energy for mild tasks only, will be as truly in a state of chronic inanition as is one who through accident, disease or misfortune is obliged to sustain himself on a limited quantity of food. In either event there will be a negative balance between the income and output of energy, a shortage which the organism must make good by infringing slowly but none the less persistently upon its stored reserves." [1]

No appetite is entirely trustworthy; if no attention is paid to the energy value of the food, fluctuations in

[1] Morgulis, Sergius. *Fasting and Undernutrition*, page 261. E. P. Dutton and Co. (1923).

the amount eaten from meal to meal and day to day may be very great. In a study of the individual food consumption of a group of healthy and presumably well-fed girls from ten to twelve years of age,[1] living in the same house and eating at the same table, there was found to be a great deal of variation in the amount eaten from day to day. This was especially true in regard to the dinners. By weighing each girl's food for a number of days it was discovered that the greatest single cause of this variation was the presence or absence of milk from the menu. Within a month, 61 dinners weighed on days when milk was not given as a beverage averaged 619 calories, while 23 dinners when milk was supplied averaged 1,038 calories, an increase of 68 per cent. The study also showed that if the main dish and the dessert both happened to be low in calories when no milk was furnished a dinner might have only half as many calories as the one the next day. The ease with which two people sitting at the same table can vary their food intake is shown by the two breakfasts from the same menu on page 109.

If one trusts to appetite, how much one eats depends largely upon the attractiveness of the food. The poor without vigorous appetites often find little inducement to eat in the character of the food on their tables. They cannot afford the alluring cream, butter, eggs, and fruit which add more calories than necessary to the diets of the rich, to say nothing of other foods which by attractive color, form, and flavor constantly give interest to the tables of the well-to-do and make eating

[1] Made by Cora E. Gray for the Institute of Child Welfare Research, Teachers College (1925).

the "most popular indoor sport." When college students plan and prepare a meal with regard only to pleasing their palates, they are apt to eat from 25 to 50 per cent more calories than when they provide for themselves a meal of minimum cost, and they regard the eating of the lesser number of calories in the low-cost meal as a much greater task. Poverty may also

TWO BREAKFASTS FROM THE SAME MENU

Food	Breakfast I		Breakfast II	
	Measure	Calories	Measure	Calories
Orange	1/2	50	1	100
Sugar	None	0	2 tsp.	40
Grapenuts	2 tbsp.	66	3 tbsp.	100
Sugar	None	0	1 tsp.	20
Cream	1/3 c. thin	150	1/3 c. thick	280
Toast	1 slice	50	2 slices	100
Butter	1/2 tbsp.	50	1 tbsp.	100
Coffee	1 c. clear	0	with 1/2 c. milk	85
Sugar	1 tsp.	20	2 tsp.	40
Total		386		865

induce undernutrition because of inability to secure sufficient food, which in turn reacts to decrease appetite. Chronically underfed children are less hungry than one would expect and have to be educated to a higher food consumption.

Some apparently normal individuals who are thin have to force appetite a great deal in order to increase their weight. Gulick has given an interesting account of a study made on himself in which food intake was definitely controlled for a year and nine months. His ordinary weight was about 62 kilograms and customary food intake about 2,750 calories. During the experiment he maintained for 20 consecutive days, on an

intake of 3,200 calories per day, a constant body weight of 61.5 kilograms; then he gradually increased his food intake from 3,600 to 4,100 calories, "eating persistently more than was relished," whereupon his weight gradually rose to 74.7 kilograms, a gain of 13.2 kilograms or 29 pounds. In order to retain the extra weight, it was necessary to keep up the high food intake.[1]

Sometimes the root of undernutrition is worry—a proverbial destroyer of appetite. One young woman who wished to reduce her weight and found great difficulty in doing so was heard to exclaim, "I'd go down fast enough if I could only get up a big worry!" Children often suffer from underweight due to unhappiness and nervousness caused by an unfavorable home atmosphere, and improve amazingly in regard to food consumption and body weight when changed to a more favorable environment.

Another common cause of inadequate appetite and undernutrition is fatigue. Several hundred college women in response to a questionnaire gave this as the commonest cause of failure of appetite in their own personal experience. In young children fatigue is undoubtedly very frequently responsible for reduced food intake, and probably affects in other ways the efficient use of food by the body. Children need to be carefully watched as regards the time spent in sleep and rest and to be safeguarded against playing to the point of exhaustion.

Many times loss of appetite is due to some physical defect or disease: enlarged tonsils and adenoids, inter-

[1] Gulick, A. "A Study of Weight Regulation in the Adult Human Body During Over-Nutrition." *American Journal of Physiology*, Vol. 60, page 371 (1922).

fering with full respiration; infected teeth and tonsils, constantly poisoning the body; and latent infectious diseases such as tuberculosis are among the common causes of undernutrition reported by child health stations and clinics. Not only tuberculosis but also various diseases of the nervous system and of the alimentary tract seriously impair appetite and in this and other ways bring about undernutrition.

It must be borne in mind, too, that a diet reduced in total calories is likely also to be below the optimum in one or several of its other dietary essentials. Sherman and Gillett, in their study of 92 family dietaries in New York City,[1] found that "freely chosen dietaries contained a liberal surplus of protein and a fair supply of phosphorus and iron but scarcely more than is actually necessary of calories or of calcium." The simple expedient of increasing the total amount of food would in many instances have made good the shortage of both calories and calcium.

Safeguarding Digestion

Sometimes attempts to gain weight are discouraging because the person's digestive system is unequal to the new demands abruptly made upon it. Increases should not be too sudden. The girl who learned that peanut butter was high in calories and proceeded to dispose of half a pound (1,370 calories) a day in addition to her regular diet came quickly to grief because she had overtaxed her digestive powers. It is not enough to know how much energy is needed. We must

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 552. The Macmillan Co. (1926).

also known how to furnish it so as to prevent disturbance of the machinery. No one can deal successfully with dietary problems who does not understand the relation of food to the alimentary tract as well as the kinds and the quantities of food needed by the body. Specialized study of the structure and functions of the digestive system belongs to physiology and is not within the scope of this book, but the way food affects the digestive tract is a very important part of practical nutrition.

The three kinds of fuel food are used to best advantage when carbohydrate predominates, and neither fat nor protein is present in very high proportion. While fat is our most concentrated form of fuel, it has to be used with discretion or we may defeat our own ends. Protein in moderate amounts contributes satisfactorily to the total energy intake, but protein alone burns wastefully, many calories being unavailable for work or storage (see page 48). Carbohydrate in the form of sugar is most attractive, but sugar blunts appetite unless carefully managed. Mrs. Squeers of Dotheboys Hall knew this, for she gave treacle (molasses) to her wretched protégés "partly because it spoils their appetites and comes cheaper than breakfast and dinner." Sugar in concentration irritates the stomach and may be the cause of headaches, skin eruptions, and other ills. Starch is easy to digest, but too much may ferment before it has had time to be absorbed and so do more harm than good.

In everyday life, fully 75 per cent of the common dietary problems relate to digestion. This is why one who wishes to become an expert dietitian must have a thorough fundamental training in chemistry, biology,

and physiology. There are no short cuts to an understanding of the way the human body works. Without such a training, no one will have the convictions which will enable him to insist upon a proper dietary program in view of the fact that few people are killed by a single dietary indiscretion and many survive years of rash living. The thin person needs first to make himself as well as possible, so that he will agree with his food. At the same time, certain general principles of making food itself easier to digest may profitably be applied.

For the greatest comfort, food should digest fairly rapidly. This is especially true if a larger amount than usual is to be eaten. As rapidity of digestion is fostered by having the food in fine particles when it enters the stomach, mastication becomes a special virtue. Toast, zwieback, triscuit, bread dried hard in the oven, crusty rolls, crisp, dry corn flakes, grape-nuts, shredded wheat, etc., are desirable forms of bread, because they induce mastication and in the process absorb saliva like a sponge, thus further accelerating the speed of their digestion.

Fat, digesting slowly and tending to retard the digestion of other foods, especially those rich in protein, must not be used too freely, for slow digestion tends to impair appetite for the next meal. Fat meats, such as pork, are an excellent example of food slow to digest because of fat mixed with the protein.

The principles of feeding in undernutrition find special application in tuberculosis, where the body's ability to fight the disease depends upon developing a good state of nutrition in spite of an almost invariably

fickle appetite and poor digestion. Fresh air, sunshine, rest, and food of suitable amount, appetizing and easy to digest, at regular times, and in specified amounts are prime features of treatment.

The exact number of calories which any person will require to induce gain in weight cannot be determined definitely in advance, but must be gauged by watching the scales. Those who do not fatten easily need all the more to learn to live on a high nutritional plane. It may not be possible for them to get much fatter, but they will surely feel better, as they thus safeguard themselves against further undernutrition.

Section 2

SURPLUS OF CALORIES

Who does not remember Mrs. Manson Mingott, the "venerable ancestress" in the *Age of Innocence*, whose habit it was to sit in her room on the ground floor waiting for life and fashion to come to her, since she was unable to follow them even to the grand reception room of the second floor of her Fifth Avenue mansion? Mrs. Wharton has described her inimitably: "The immense accretion of flesh which had descended on her in middle life like a flood of lava on a doomed city had changed her from a plump active little woman with a neatly-turned foot and ankle into something as vast and august as a natural phenomenon. She had accepted this submergence as philosophically as all her other trials, and now, in extreme old age, was rewarded by presenting to her mirror an almost unwrinkled expanse of firm pink and white flesh, in the center of

which the traces of a small face survived as if awaiting excavation. A flight of smooth double chins led down to the dizzy depths of a still-snowy bosom veiled in snowy muslins that were held in place by a miniature portrait of the late Mr. Mingott; and around and below, wave after wave of black silk surged away over the edges of a capacious armchair, with two tiny white hands poised like gulls on the surface of the billows." [1]

Many another woman has been forced by the accumulation of body fat so common with advancing years to keep off her feet or suffer because her body has become too heavy for them to carry. We realize the handicap of obesity when it thus impedes locomotion and engenders flat foot, but we should also realize that the internal organs are working under a handicap like that of the feet. The muscles when clogged with fat become soft and flabby; the heart in particular suffers in this way. The circulation of the blood is impeded and this in turn makes the work of the weakening heart more difficult and the strain on the blood vessels greater. Liver, kidneys, and pancreas all are at a disadvantage, and how long they can continue to function properly depends on their native endurance. There is no guarantee that a pancreas able to take care of a 150-pound body can take equally good care of one weighing 300; in fact, there is evidence enough to be strongly suggestive that diabetes is the penalty for obesity. Certain diseases have long been known to be associated with overweight. Life insurance companies are reluctant to place standard insurance on people with marked overweight, and where it is excessive, may

[1] Wharton, Edith. *The Age of Innocence*, page 25. D. Appleton and Co. (1920).

refuse insurance altogether. This attitude of the insurance companies shows that they consider overweight a very serious disability.

Mode of Life and Food Consumption

It is clearly important to check the tendency to increasing weight by such changes in mode of life, especially in diet, as will prevent any undue accumulation of body fat. At age 50, people from 20 to 30 pounds below the ordinary average for their age seem to be in best condition. We have seen that the basal metabolism of adults falls slightly year by year. Exercise, too, seldom fails to diminish in duration and in intensity; yet the appetite for food continues or even increases. So, more and more, food is eaten which is not needed and the extra fuel is stored as body fat. While some persons undoubtedly store fat much more readily than others, it is not generally attributable to any fundamental peculiarity in their basal metabolism. Per square meter of body surface there has been found very little difference between fat and thin.[1] Recent experiments by Wang, Strouse, and Saunders [2] indicate that the very obese exhibit a tendency to store fat rather than burn it and to use protein without as much waste (specific dynamic action) as the common run of people; this tendency, however, is not marked in those only a little overweight. The latter simply need to learn to get a balance between calorie intake and

[1] Cf. page 68. Also DuBois, E. F. *Basal Metabolism in Health and Disease*, page 185. Lea and Febiger (1924).

[2] Wang, C. C., Strouse, S., and Saunders, A. D. "Studies on the Metabolism of Obesity III. The Specific Dynamic Action of Food." *Archives of Internal Medicine*, Vol. 34, pages 573–583 (1924).

energy expenditure. An inclination toward obesity may be constitutional; a cheerful disposition, a very stable nervous system, incapacity for worry, ability to work with great economy of muscular effort, lack of interest in cold baths or hot athletic contests may be a part of one's inheritance. Furthermore, when riding in automobiles, watching movies or baseball games, and sitting at bridge parties are the most active forms of sport, exercise is reduced to a level incompatible with the combustion of many calories in excess of the basal metabolism. If we propose to lead sedentary lives, we should learn to lead them well. The greatest obstacle is habit. One must plan a program which one can remember. The best way is to determine the number of calories one should have for each meal and see that one does not exceed the limit. There need be no radical change in the general character of a dietary program which already includes suitable kinds of food. Sometimes staying away from the table for one meal (breakfast or luncheon), taking only some fruit by one's self, keeps one from falling into one's former habits; provided of course, that one does not visit pantry, refrigerator, soda fountain nor afternoon tea table and there make up everything lost by one's self-denial at meal time.

The Control of Hunger

Hunger is a great inconvenience when one wishes to reduce one's food intake. It is well to remember that hunger is the sign of a vigorous stomach emptying itself quickly and not the signal of danger of immediate starvation. Hunger pangs will seem less alarming if reckoned at their true value; nevertheless they are

extremely uncomfortable and hence it is well to seek some way to allay them. Sometimes drinking water will assuage them temporarily. Eating food with much vegetable fiber is a help as it gives a sense of fullness, which is a part of the normal satisfaction of hunger. There need be no limit to the amount of lettuce, cabbage, string beans, celery, chard, brussels sprouts, asparagus, and other greens, and there should be a real effort to increase the amount of such food to many times what is ordinarily eaten. Instead of two or three lettuce leaves, take at least half a solid head; instead of a bit of cabbage as a side dish, take two or three cupfuls of raw shredded cabbage. Raw fruit such as apples, oranges, grapefruit, and other fruits in season should so far as possible take the place of other desserts. Some fat is a help in controlling hunger and can be used if sufficient attention is paid to the total calories, which, of course, are rapidly increased by this concentrated form of fuel. The fat should be put where it will count most, on the table where one can see it, and not in the food while cooking. Mineral oil, which has no food value, may be used in making salad dressings, and vegetable gelatin, also devoid of calorie value, may be the foundation of some acceptable desserts. Sometimes a piece of sweet chocolate or a cup of sweetened tea in the middle of the forenoon or of the afternoon enables one to tide over without faintness till the next meal, but the calories so taken must be counted as part of the day's total.[1]

[1] For assistance in planning diets, see Rose, M. S. *Feeding the Family*, 2d edition. The Macmillan Co. (1924). Peters, L. H. *Diet and Health with Key to the Calories.* The Reilly and Lee Co. (1921). Howk, H. J., and Fellows, H. H. *Overweight, its Cause and Treatment.* Metropolitan Life Insurance Co. (1924).

Adjusting Energy Intake and Energy Expenditure

The scales should be watched week by week. Gain or no gain is the final test of the diet. If one is gaining, there are too many calories. Adjust them until weight remains stationary; or, if overweight, until losing at the desired rate, which should not be over a pound a week. Remember that 200 calories a day stored mean 17 pounds of body fat in one year, and that one insignificant chocolate caramel yields 100 calories; one bar of sweet chocolate, 150 or 175 calories; one sundae at the fountain, 500 calories.

In addition to limiting the calories, it is desirable to increase the energy expenditure by exercise and cold showers. The exercise should be moderate and over a considerable period of time; the "daily dozen" should be raised to a "daily score." The cold showers not only raise basal metabolism at the moment, but continue to stimulate it for some time afterwards. A bath with the water at about 60° F. has been found to double the energy expenditure, and one with the water at 40° F. may be counted on to treble it! Of course, one must very gradually accustom himself to such cold baths, beginning with water about 65° F.

Obesity in the Young

Obesity is not characteristic of youth. Under thirty years of age the natural tendency is toward under and not overnutrition, yet a few children are overweight for height and age. Sometimes this is because they are lazy and overfed; increasing their activity and curtailing sweets (usually the cause of surplus of calories

in such cases) will bring them to a better condition. Sometimes the cause is pathologic. Reference has been made in Chapter IV to the glandular mechanism regulating basal metabolism. An abnormally low basal metabolism is taken as one of the clinical signs of insufficient activity of the thyroid gland. Ordinarily, however, obesity in children does not seem to be explainable as due to disturbance of thyroid, pituitary, or other glands, and requires much more study than it has as yet received.

Obesity is a handicap to children, because they do not fit so well into the regular athletic and play program and are more liable to accidents and strains. Veeder, from a four-year study of 200 private school boys ranging from nine to seventeen years of age, calls the overweight boy as much of a problem as the underweight. "The fat boy is too heavy to fit in with hard exercise or play, such as football, with boys of his own class and age, and too young and immature to play with boys of his own weight but older in years and stronger. In games requiring more skill, such as baseball and tennis, they are decidedly awkward and backward as a group and hence we find them with the tendency to withdraw from competitive play and loaf, with the result that these overweight boys, who are in particular need of exercise, are the ones who have to be continually driven and supervised."[1]

It does not seem wise to reduce the weight of a growing child except under special medical supervision, but it may be possible to hold his weight stationary for

[1] Veeder, B. S. "The Overweight Child." *Journal of the American Medical Association*, Vol. 83, page 487 (1924).

a period until by suitably planned exercise he has lowered his excess of fat tissue. As a rule, children do not enjoy being obese and are willing to coöperate in measures to bring their weight to normal, but they gain easily and care must be given to them over a long period of time. Children easily learn to count their own calories and can thus help themselves. It is important to see that each such child gets as a part of his ration three glasses of milk and one egg daily, at least 300 calories of whole wheat bread and potatoes together, and some fruit and some vegetable besides potatoes at every meal, with no candy, cake, preserves, syrups, etc., and nothing whatsoever between meals except water.

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CHAPTER VII

THE BODY'S NEED FOR BUILDING MATERIAL AND FOOD AS THE SOURCE OF SUPPLY

The Essentials for Body Building

The beginning of a human being is an egg too tiny to be studied with the naked eye. Initiated by the union of sperm and ovum, a complicated system of chemical processes which we call life at once enables the minute organism to take up materials from its environment for its own growth. During its prenatal life the human fetus increases its weight more than five million times. By the fourth month of intra-uterine life it may have attained a weight of 36 grams; at birth it will have increased this latter weight one hundred times. Even after birth the increase in substance is great. A newborn baby weighs on the average from 7 to 7.5 pounds; the adult into which he grows may weigh twenty to thirty times as much. The calories represented in the body of a four-months fetus are about ten; in the infant at term, about 4,000;[1] in the average adult man over 50,000 from protein alone and probably half as much more from fat and glycogen. The major portion of the energy-yielding materials ingested must be spent in the maintenance of internal and external activity, but a certain part must also be

[1] From data of Czerny and Keller, cited by Jordan, W. H. *The Principles of Human Nutrition*, page 261. The Macmillan Co. (1912).

retained for growth. Up to the time of birth the human fetus stores daily an average of at least three grams of protein and eight grams of fat.[1] An infant ingesting 520 calories and gaining 3 grams of protein and 3 grams of fat in a day will have stored 40 calories, or 8 per cent of the total calories eaten.

The protein is an essential component of every living cell in the body and makes up a large part of the solids of a muscle cell; a small portion of the fat enters into the composition of nervous tissue; the rest is stored as adipose tissue. Carbohydrates we find also in the living body, not only as a source of energy but as constituents of certain indispensable proteins and certain other compounds found in the brain and nerves. Even starvation does not deprive the blood of all its sugar.

Thus from the stream of energy-yielding proteins, fats, and carbohydrates continually passing through the body as we eat, digest, and assimilate our food, materials for constructive purposes are withdrawn as needed. Similarly water, whose constant flow through the body is one of the conditions of life, is an essential part of the body structure, constituting about three-fourths of the body weight in the newborn and about two-thirds in the adult.

In addition to proteins, fats, carbohydrates, and water, we find in the body an assortment of mineral elements including calcium, chlorine, fluorine, iodine, iron, magnesium, manganese, phosphorus, potassium, silicon, sodium, and sulphur. These mineral elements

[1] Feldman, W. M. *Ante-natal and Post-natal Child Physiology*, pages 134–135. Longmans, Green and Co. (1920).

are commonly referred to by the inclusive term mineral salts, or ash constituents. Equally important with the supply of energy is the supply of each chemical element in the amount needed. A shortage of any one, no matter how minute the daily requirement, will interfere with normal nutrition. The fetus stores on the average only about three-fourths of a gram of assorted mineral salts per day.[1] In the fortieth week of pregnancy, when the total daily storage is at its height, it has been estimated[2] to be for phosphorus, 0.18 gram; for calcium, 0.3 gram; and for magnesium, 0.009 gram. The other elements must be retained in still smaller amounts. Yet only when every element is properly represented can the body maintain its health, replace worn-out parts, and construct new materials in the process of growth. In this chapter we shall consider (1) protein, (2) ash constituents, and (3) water, as essential body-building materials.

Section 1

PROTEIN AS BUILDING MATERIAL

Muscular work is done preferably and most economically at the expense of carbohydrate food. Mixtures of fat and carbohydrate in which carbohydrate predominates are burned with practically the same ease as pure carbohydrate. Fat alone is utilized with less ease than a mixture of the two and with a "cost" of from 8 to 12 per cent of its energy value. Protein can be economically used when a small proportion is

[1] Feldman, W. M. *Ante-natal and Post-natal Child Physiology*, page 135. Longmans, Green and Co. (1920).

[2] Michel, cited by Lusk, Graham. *The Elements of the Science of Nutrition*, page 389. W. B. Saunders Co. (1917).

mixed with carbohydrate or carbohydrate and fat, but when taken as the sole source of energy, is burned at a rate that is wasteful in the extreme. As long as carbohydrate and fat are available, muscular work is not done at the expense of the protein supply. When protein is used as fuel, the nitrogen which it contains is not an asset but a liability, to be got rid of as speedily as possible. The protein is transformed within the body into simpler compounds which will be described presently and the nitrogen is excreted in the urine, chiefly in the form of urea, together with a relatively small amount of ammonia. Then the protein, freed of its nitrogen, is burned.

When protein is used as building material the story is very different. Then the nitrogen is the prime consideration. Every living cell is continually demanding it for upkeep, working it over into living tissue, and ultimately discarding it again in the form of other simpler compounds (chiefly uric acid from all kinds of active cells and creatinine from muscle cells) which are excreted in the urine. In the human adult the creatinine excreted ranges from 7 to 11 milligrams per kilogram of body weight or from 1 to 2 grams per day; the uric acid averages about 0.6 gram per day; both together are usually less than 10 per cent of the total nitrogen of the urine.

This is the maintenance requirement for protein, which continues throughout life and is independent of muscular activity. In addition to this maintenance requirement for every one we have in youth, as already indicated, a growth requirement—an additional and more specialized need of protein for the building of

new body substance. This growth requirement makes the total protein requirement of childhood higher in proportion to size than that of the adult. Only under certain circumstances do we have in adult life a growth requirement superimposed on the maintenance requirement; these are chiefly:

(1) In athletic training, when muscles increase in size.
(2) After a wasting disease, when muscles are regaining substance lost.
(3) In pregnancy, owing to growth in the maternal organism.

The Chemical Nature of Protein

In order to understand protein requirements and how to meet them, it is necessary to know something about the chemical structure of protein itself. The term stands for a large number of related substances all made by the union of simpler substances containing nitrogen, called amino acids. There are 18 of these commonly found in food and body proteins, all having certain characteristics in common, but each one exhibiting properties which mark it as a distinct chemical entity. The names of these 18 common amino acids are as follows:

Alanine	Lysine
Arginine	Ornithine
Aspartic acid	Oxyproline
Cystine	Phenylalanine
Glutamic acid	Proline
Glycine	Serine
Histidine	Tryptophane
Hydroxyglutamic acid	Tyrosine
Leucine	Valine

A protein is a very complex substance. We may get some idea of how it is constructed from the amino

acids listed above if we think of a large assortment of beads of 18 kinds, each a different color and size and many of each kind in the lot. To represent a protein we may select one sample of each of our different beads and arrange a figure; or we may take the same 18 amino acids, some kinds singly, others by threes or fours, perhaps some by the dozen, and arrange another figure of quite a different pattern. Each would typify a protein but the two would have quite a different composition, though built from similar units. Some proteins have only 17 amino acids represented in their structure, others only 15 or 16, and these also may be varied by different proportions of each of the kinds present. Here for example is the chemical analysis of two proteins, casein from milk and zein from our common Indian corn.[1]

THE AMINO ACID CONTENT OF TWO KINDS OF PROTEIN

	Casein, Per Cent	Zein, Per Cent
Alanine	1.85	13.39
Arginine	3.81	1.82
Aspartic acid	4.10	1.80
Cystine	0.50	0.85
Glutamic acid	21.77	26.17
Glycine	0.45	Absent
Histidine	2.84	0.82
Leucine	9.70	19.55
Lysine	7.62	Absent
Oxyproline	0.23	?
Phenylalanine	3.88	6.55
Proline	7.63	9.04
Serine	0.50	1.02
Tryptophane	2.20	Absent
Tyrosine	6.50	3.55
Valine	7.93	1.88

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 59. The Macmillan Co. (1926).

It will be noted that the proportions of amino acids in the two are very different and that, while casein is not entirely lacking in any amino acid in the list, zein lacks three at least.

Essential Amino Acids and Their Sources

Some amino acids are relatively more important than others. Glycine and alanine can be made in the body from other amino acids, just as a suit for a small boy can be cut from father's larger one. Tryptophane, on the other hand, cannot be manufactured by the cells from any other amino acid. It must occur in the food as such, for without it no continuation of life is possible. The same is true of histidine. Cystine is unique in its content of sulphur and not replaceable by any other amino acid in our list. Tyrosine and phenylalanine are similar and can replace each other, but one of them must be present in the diet. Lysine is essential for growth although not for the maintenance of the adult, and the same seems to be true of proline. An interesting example of maintenance on a protein inadequate for growth is furnished by gliadin, one of the proteins of wheat. The illustration shows a rat fed for 140 days on gliadin in contrast with a rat of the same age fed a normal diet for the same period. The smaller animal remained healthy, but its growth was completely arrested. That the difficulty was due to lack of lysine was demonstrated by the prompt response in growth upon the addition of pure lysine to the gliadin diet.

In daily life it is not practical to use pure amino acids, but it is quite possible to combine two or more proteins so that the deficiencies of one may be made good by another. Thus, instead of adding lysine to

gliadin we can secure equally good results by replacing part of the gliadin by the proteins of milk.

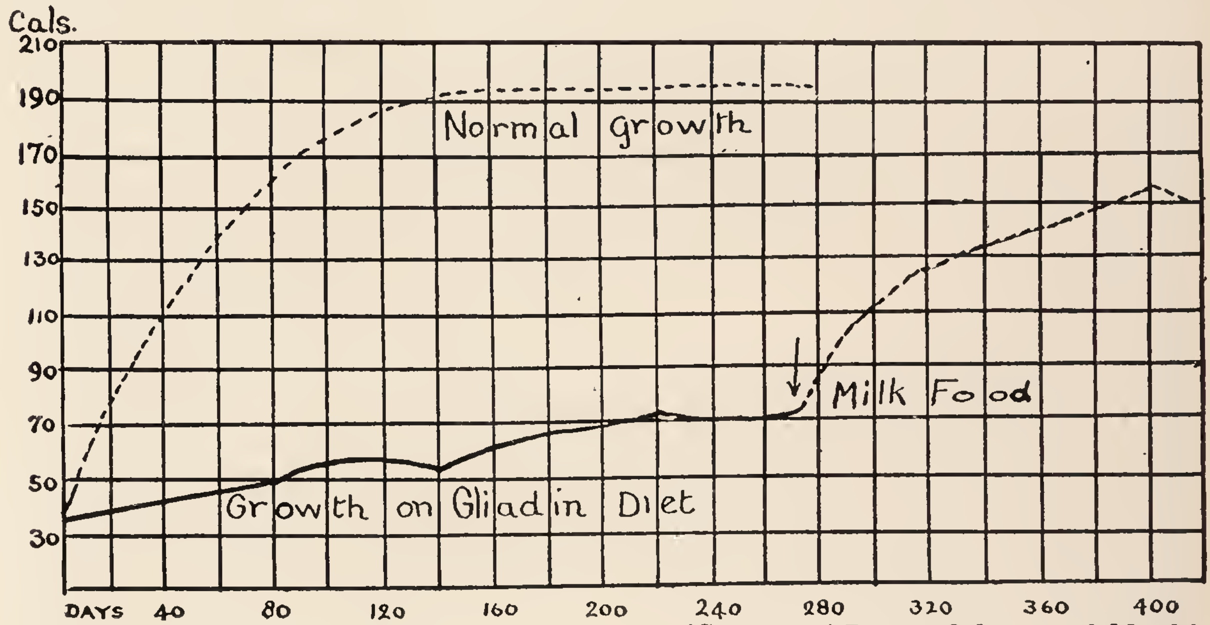
If we have a protein not entirely deficient in a given

(*Courtesy of Professor L. B. Mendel*)

FIG. 30.—The two upper rats are five months old and have been fed on diets exactly alike except for the protein, which was the casein of milk for the uppermost and gliadin of wheat for the second. The first grew normally; the second at the age of five months weighs what it should have weighed at one month. The third rat is the same weight as the second, but one month old instead of five.

amino acid but yielding only a small quantity, we can make good the deficiency either by more of the same food or by combination with another food richer in that particular amino acid. Referring to the composition of

casein on page 127, it will be seen that it does not contain a very high proportion of cystine. When casein is the sole protein in the diet of a rat it must constitute 18 per cent by weight in an otherwise adequate diet to get normal growth; if the casein is fed at a level of 9 per cent, growth will be distinctly retarded, but an addition of cystine will cause resumption of normal growth. Instead of the pure cystine, we might use



(*Courtesy of Doctors Osborne and Mendel*)

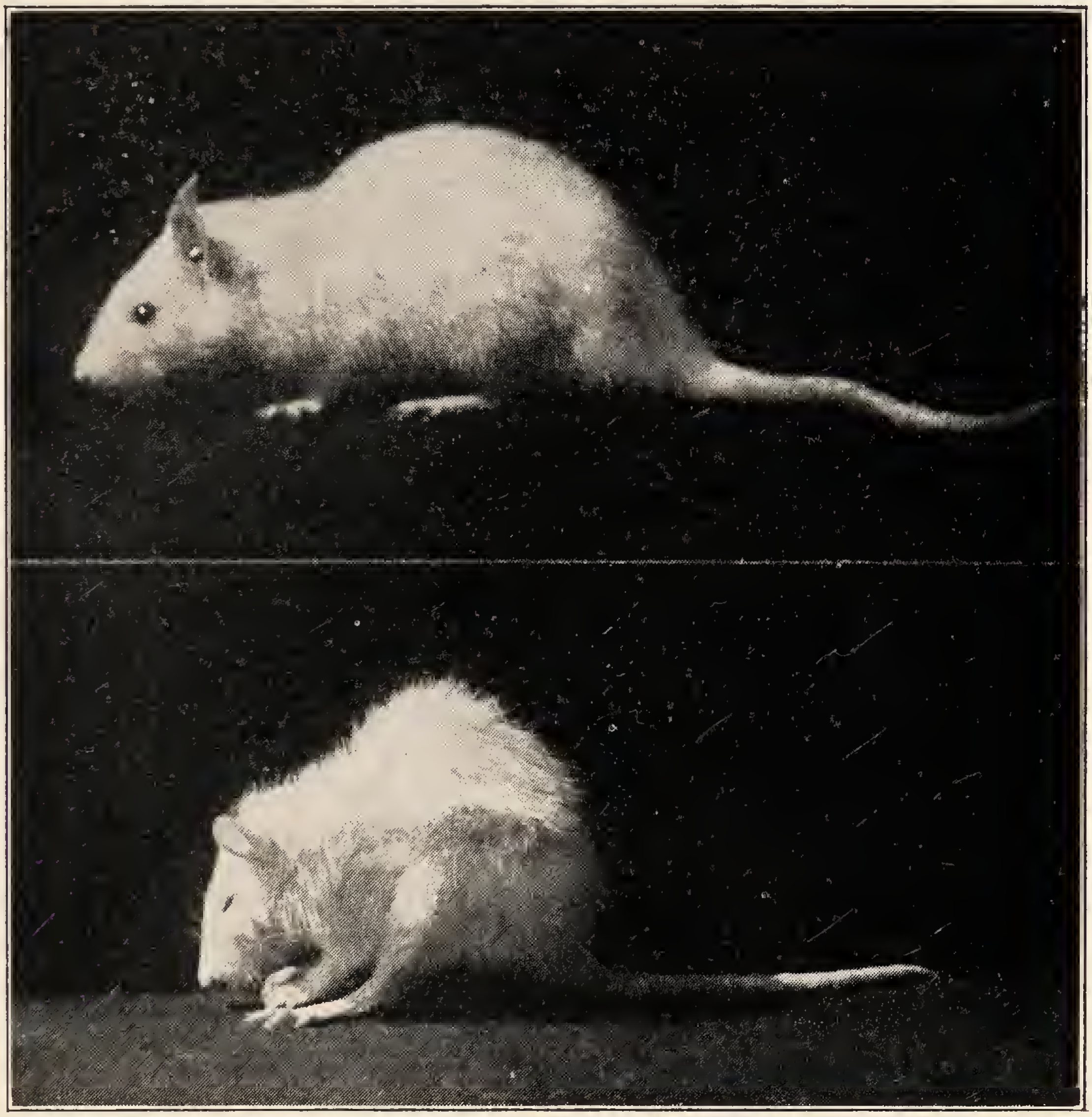
FIG. 31.—The growth record of a young rat placed at weaning time upon a diet containing gliadin as the sole protein, and kept on this diet until 276 days old. At this time milk food replaced the gliadin food, and the animal was able to grow at a good rate although of an age at which normal rats have usually ceased to grow.

egg albumin, rich in cystine, and then we should need less total protein than with casein alone.

The experimental removal of histidine from casein leaves an amino acid mixture upon which rats promptly and continually lose weight. The result of a histidine-free diet for 169 days as compared with an animal of the same age on the same diet plus histidine is shown in Fig. 32.[1]

[1] Rose, W. C. "The Relation of Arginine and Histidine to Growth," *Journal of Biological Chemistry*, Vol. 61, page 747 (1924).

Proteins which will maintain life but lack some amino acid essential to growth are called *partially incomplete.* Thus gliadin, which lacks lysine and has already been



(*Courtesy of Dr. W. C. Rose*)

FIG. 32.—The upper rat (No. 17) was on a diet adequate in all respects. The lower (No. 13) had a diet similar in every way except that the amino acid histidine had been removed and the amino acid arginine substituted for it. Histidine is thus shown to be an indispensable constituent of the diet.

shown to support life but not growth, is partially incomplete. Proteins capable of sustaining life and promoting growth are called *complete;* casein of milk is such a protein.

Reference to tables of food composition [1] show us

[1] Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition. The Macmillan Co. (1921).

that proteins are present in many common food materials, but not in all. Fat and sugar yield none. Some foods have very little in proportion to their weight; for example, most fruits and vegetables. Other foods are very rich in protein, as eggs, cheese, nuts,

CHARACTER OF PROTEINS IN SOME COMMON FOODS

FOOD MATERIALS	CHIEF KINDS OF PROTEIN PRESENT	COMPLETE OR INCOMPLETE
Almonds	Excelsin	Complete
Cheese	Casein Lactalbumin	Complete Complete
Corn	Glutelin Zein	Complete Incomplete (lacks lysine and tryptophane)
Eggs	Ovalbumin Ovo-vitellin	Complete Complete
Gelatin	Gelatin	Incomplete (lacks tryptophane and tyrosine; only a trace of cystine)
Lean meat	Albumin Myosin	Complete Complete
Milk	Casein Lactalbumin	Complete Complete
Navy beans	Phaseolin	Incomplete
Peas	Legumin	Incomplete
Soy beans	Glycinin Legumelin	Complete Incomplete
Wheat	Gliadin	Partially incomplete (lacks lysine)

and lean meat of all kinds, whether from four-footed, swimming, or flying creatures. Cereals are not very rich in protein, but on account of the relatively large amounts eaten by the human race are of considerable importance. Among other vegetable foods, the legumes, especially peas, beans, and peanuts, are comparatively

high in their yield of protein. Tables giving simply the total amount of protein present tell us nothing, however, about the kinds of protein occurring in the different food materials.

The table on page 132 shows the chief kinds of protein in some of our common food materials with reference to their nutritive efficiency. From this it will be seen that in ordinary daily life our chances of getting none but incomplete proteins are small; in animal food, such as milk, cheese, eggs, and meat, the various proteins present are all complete, but in vegetable foods very commonly an incomplete protein is associated with a complete one; occasionally, as in the case of the navy beans, the total protein content seems of relatively poor quality. The supplementing value of one protein for another must, however, be kept in mind. The supplementing value of milk is exceedingly high. An instance is furnished by an experiment on growing pigs, in which one lot received protein only in the form of corn, which, it will be noted, contains the incomplete protein zein not compensated for by the complete protein glutelin; the other lot was given corn plus casein equal to about one-tenth of the corn. The corn lot grew in 180 days from an average initial weight of 25.3 to an average final weight of 37.6 pounds, whereas the average change in the corn-casein lot was from 31 to 142 pounds. Here a comparatively small addition of casein changed the ration from one that permitted practically no growth to one that permitted approximately two-thirds normal growth.[1]

[1] Hogan, A. G. "Corn as a Source of Protein and Ash for Growing Animals." *Journal of Biological Chemistry*, Vol. 29, page 485 (1917).

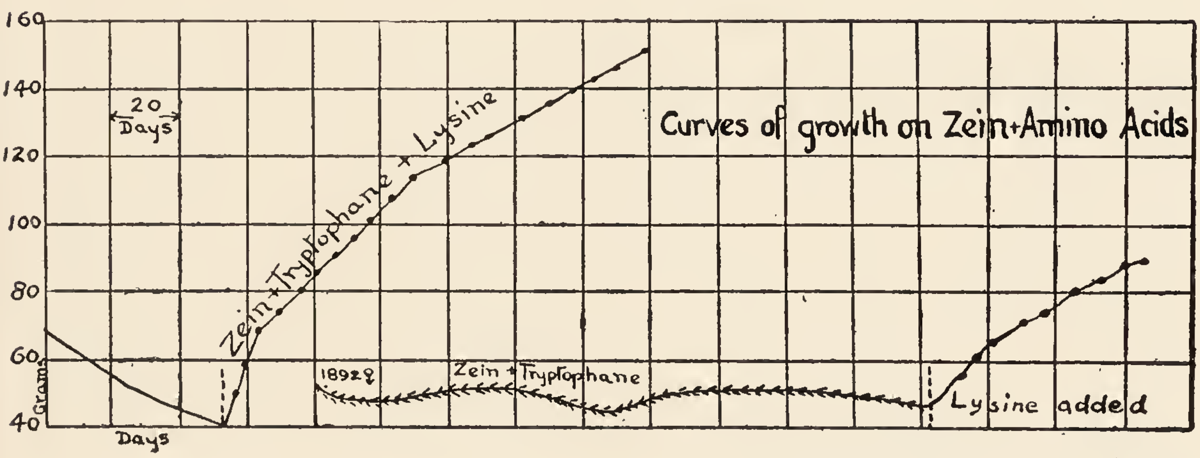
The nutritive value of a protein mixture can be predicted only as the amino acid content is known. As yet such analyses of proteins are not numerous. We must, then, in each case of uncertainty have recourse to laboratory animals and by carefully regulated feeding experiments determine the efficiency of any food or mixture of foods in question. Since this is laborious and time-consuming, it is a comfort to know that the protein deficiencies of cereal grains and legumes can readily and economically be made good by the liberal use of milk in the diet, and less cheaply but also effectively by eggs and other animal foods.

The Protein Requirement for Growth

The nutritive value of any protein or mixture of proteins depends, as we have already seen, upon the assortment of amino acids which it furnishes and their relation to the needs of the cells. The efficiency of the amino acid mixture determines the quality of the total protein of the diet. In the full-grown man or woman considerations of quality are not so pressing as in the young child, because we are concerned chiefly with the conservation of tissues already formed, and even an incomplete protein like the zein of maize, inadequate for maintenance and incapable of supporting growth, is capable of protecting the body tissue to the extent of 73 per cent. But body-building can proceed only when the zein is supplemented by the amino acids tryptophane and lysine. The situation is similar to that in which the builder of a frame house with brick foundation would find himself if there should be delivered plenty of wood for walls and glass for windows

but no bricks. Obviously construction would be held up till the bricks were forthcoming.

In infancy growth proceeds at such a rate that the newborn child doubles its weight in six months and triples it in a year, and we find that as much as one-third of the protein intake may be stored as body protein. Rubner even reports [1] a study of a premature infant who for 38 days retained for growth one-half the protein eaten. To get the best storage, the protein of the



(*Courtesy of Professor L. B. Mendel*)

FIG. 33.—The solid line shows the decline in weight when zein of maize is the sole protein of an otherwise adequate ration. With zein plus tryptophane weight is maintained, but there is no growth. When lysine is added as well as tryptophane, normal growth is possible.

food must be in itself efficient in promoting growth and the supply of carbohydrate and fat must be liberal enough to protect the protein from being burned as body fuel. Milk is distinctly richer in tyrosine, tryptophane, and lysine than the common run of food proteins, and the amino acids least liberally supplied are those most easily derived from other foods. "With a full quart of milk in the daily dietary of the growing

[1] Cited by Lusk, Graham. *Science of Nutrition*, 3d edition, page 390. W. B. Saunders Co. (1917).

child, the other foods may be selected chiefly with reference to other qualities than their protein content." [1]

Because the protein requirement during growth is high, we cannot assume that there is no limit to the amount which can be given with profit. Both Holt and Hoobler have remarked in their studies with human infants failure to gain and other unfavorable symptoms when one-fourth or more of the total calories of the diet came from protein. Experimentally, Hoobler found that he secured the best retention in growth when 7 per cent of the total calories came from protein. In human milk about 9 per cent of the calories are in the form of protein. Sherman summarizes our present knowledge thus: "If then, the full-grown man and the child at the time of most rapid growth each requires but 10 per cent of his calories in the form of protein, it seems probable that this proportion is also sufficient for any intermediate age, if the diet is of ample fuel value and the protein is of the right kind." [2]

Practically, it is not possible to keep the protein as low as 10 per cent of the total calories and still observe the rule of a quart of milk a day. There seems to be no reason why conditions for growth need be less favorable when the protein calories constitute as much as 15 per cent of the total calories. A liberal supply may be turned to good account in periods of unusually rapid growth. The yield of protein from children's diets per kilogram of body weight, at the 10 per cent and the 15 per cent levels, is shown in the following table:

[1] Sherman, H. C. *Chemistry of Food and Nutrition,* 2d edition, page 231. The Macmillan Co. (1918).

[2] Op. cit., page 230.

Protein Allowances for Children

Age, Years	Calories per kg.	Grams of Protein per Kilogram of Body Weight	
		At 15 Per Cent Level	At 10 Per Cent Level
1	90	3.5	2.2
2–5	80	3.0	2.0
6–12	70–60	2.6–2.2	1.7–1.5
13–15	60–50	2.2–1.9	1.5–1.2

From this table it is apparent that an allowance of 15 per cent of total calories in the form of protein calories gives the growing child at all ages a surplus per kilogram of body weight of from three-fourths of a gram to one and one-third grams above probable requirement, and any intermediate value should be adequate when the proteins are of good quality and the diet as a whole meets all other nutritive requirements.

The Protein Requirement of Adults

From what we have learned of the great diversity in amino acid content of different proteins, we shall not be surprised to find that when the final assortment from a meal has entered the blood stream and the cells of the tissues have begun to take up the particular kinds of amino acids which are required for their individual needs, there may be an oversupply of some and a scarcity of others. One cannot build a protein containing 18 kinds of amino acids from an assortment in which two are completely lacking, any more than one can make a dress with cloth but no thread. Nor can one build a protein containing many lysine radicals from an assortment which has very few, any more than one can make a garment from one yard of cloth when

the pattern calls for five, even though one had 100 spools of thread. It takes more casein than lactalbumin to support growth in a rat if each is fed as the sole source of nitrogen, although both are complete proteins, because the casein is not so rich in cystine as the lactalbumin and, consequently, more casein must be used, cystine being the chief source of sulphur for the animal body, as will be explained more fully in Chapter VIII. Less of a mixture of casein and lactalbumin will be needed than of casein alone because of the richer yield of cystine from the lactalbumin.

Any amino acids left over in the blood stream after the different cells have taken out the ones which meet their several needs become available for use as body fuel, just as the odds and ends of timber from the building of a house may be later turned to account in the fireplace. When amino acids are burned for fuel they are deprived of their nitrogen (deaminized) and reduced to compounds containing only carbon, hydrogen, and oxygen, which burn like sugar and fat. The nitrogen, being of no use as fuel, is converted into a relatively harmless soluble substance, urea, and this is withdrawn from the blood by the kidneys and excreted in the urine. A small part of the nitrogen never gets completely changed into urea, but escapes as ammonia. Any surplus protein is promptly burned up. We have but little power to store protein against future need as we can carbohydrate or fat. The more we eat the more we burn, and urea excretion becomes a rough measure of the amount of protein used as fuel.

The two functions of protein, as body-building material and as a source of energy, thus fit into one

another and it is impossible to tell in advance exactly how much of the protein eaten will serve each purpose. The most practical way to study the quantity of protein required is by the feeding of animals, noting just how much must be fed to sustain life without growth, and

Fig. 34.—The effect on growth of a diet in which the protein is of good quality but insufficient in amount. The diet of the rat on the left contained half as much casein as that of the one on the right. In other respects the two diets were practically alike. Both rats are the same age, 112 days.

how much must be added to insure normal growth; or by chemical studies of the nitrogen balance; i. e., the amount of nitrogen in the urine and the feces balanced against the amount in the diet.

The Effect of Fasting on Protein Output

In studying protein requirement, it is simpler to consider first the nitrogen requirement of the healthy adult, uncomplicated by the phenomena of growth.

At first thought, one might consider it possible to determine nitrogen requirement by study of the nitrogen output of a fasting individual. But here, again, several new factors appear. The amino acids needed by the cells of relatively important tissues will be drawn from small reserves of "floating" protein or from less important tissues; and the excretion of those nitrogenous compounds always being formed in active cells (such as uric acid) and in muscle cells (such as creatinine) will continue while life exists. But in the absence of food, protein will be deprived of its nitrogen and converted into sugar (glucose) to keep up the supply of glucose normal to the blood and essential to the burning of body fat for fuel. Fifty-eight per cent of the weight of the protein may thus turn to glucose and be burned along with fat for fuel, or serve as the sole source of fuel when body fat is exhausted. The nitrogen output of the fasting man is raised, then, because he uses protein for fuel, as well as for constructive purposes.

The Minimum Protein Requirement

To obviate use of protein as fuel we must feed carbohydrate, or carbohydrate and fat together, in sufficient amounts to cover the energy requirement. When we do this, we find the nitrogen output falling below that in fasting and amounting to only 2 or 3 grams per day (corresponding to 12 to 18 grams of protein), as against an output of about 10 grams of nitrogen (62.5 grams of protein) in the early stages of fasting.

But even this is not the whole story. Feeding a diet ample in calories and containing protein equivalent to 2 or 3 grams of nitrogen, we might expect to get our

fasting subject into nitrogen equilibrium. Yet only under one condition can we do so; that is, when the amino acid supply taken is exactly like the amino acid assortment needed at that moment by the cells, so that there are no leftovers to be used up as fuel. Martin and Robison, two English investigators, and Lauter and Jenke, two German workers, tried very earnestly to secure nitrogen equilibrium on the same amount of nitrogen as they found to be excreted on a non-nitrogenous diet meeting energy requirements.[1] With milk and with meat they came close to equilibrium, but never succeeded in reaching it. With wheat flour or whole wheat bread there was a considerably higher nitrogen output than on the nonnitrogenous diet.

By increasing the quantity of protein a little (22 grams of protein for a man weighing 70 kilograms) and still keeping the energy balance, we can get equilibrium quite easily with milk alone, white bread alone, or bread and milk in equal parts, and also with meat. Slightly more (35 grams per 70 kilograms) is needed with cornmeal or oatmeal and a very little milk as the sources of protein. Over 100 nitrogen balance experiments where the protein intake was kept low, various simple mixed diets being used, have been critically studied by Sherman,[2] who concludes that on the average 0.6 gram of protein per kilogram (42 grams for 70 kilograms) may be regarded as sufficient to maintain

[1] Cf. Rose, M. S., MacLeod, Grace, and Bisbey, Bertha. "Maintenance Values for the Proteins of Milk, Meat, Bread and Milk, and Soy Bean Curd." *Journal of Biological Chemistry*, Vol. 66, page 847 (1925).

[2] Sherman, H. C. "Protein Requirement of Maintenance in Man and the Nutritive Efficiency of Bread Protein," *Journal of Biological Chemistry*, Vol. 41, page 105 (1920).

equilibrium. This is the minimum protein requirement for adults.

The Optimum Amount of Protein

Since protein in excess of requirement is readily burned as fuel, there is no particular reason for trying to keep the amount in the daily diet down to the minimum. It is actually difficult to do so, on account of the richness in protein of many of our commonest foods. Moreover, considering the somewhat uncertain amino acid assortment from a diversified diet, and the likelihood of fluctuations in completeness of digestion, it would not be wise to adopt a minimum standard for practical living.

The real question, then, is not how little protein do we need, but how much is it desirable to indulge in? Mendel has shown [1] that rats can be brought to maturity with 75 per cent of their calories derived from protein. The Eskimo eats two and three times as much protein as most dwellers in the temperate zone, and a vigorous young tribesman may eat as much as nine pounds of meat daily when seals are plentiful. In the tropics, however, the consumption of protein is often not more than half that of the temperate zone. Professor Krogh, of the University of Copenhagen, estimates that the calories in the three types of diet are distributed somewhat as in table on page 143.[2] If men can adapt themselves so readily, does it make any difference how far above requirement we set our practice?

[1] Mendel, L. B. *Nutrition: The Chemistry of Life*, Yale University Press (1923).
[2] Lusk, Graham. *Fundamental Basis of Nutrition*, page 31. Yale University Press (1914).

In answering this question, we must remember that the Eskimo eats meat because he has to. An Eskimo family of four easily consumes 4,000 pounds of meat in a year, but bread, fresh vegetables, fresh fruit, salt and sweets are lacking. The children suck frozen eggs as the children of America suck lollipops. There is very little carbohydrate food to be had—a reindeer stomach now and then as a delicacy, its contents partly

Distribution of Calories in Diets of Different Races

	Weight kg.	Protein gm.	Total Calories	Distribution of Calories Per Cent		
				Protein	Fat	Carbo-hydrate
Eskimo	65	282	2604	44	48	8
Bengali	50	52	2390	9	10	81
European	70	118	3055	16	17	67

digested moss; lichens; or perhaps the skin of a young whale, rich in glycogen—so the Eskimo must manufacture from his protein the glucose which enables him to burn fat satisfactorily. Furthermore, in the Arctic winter, when "in semi-darkness the Eskimo family sits fully dressed upon the bed platform listening to the roar and whizz of wind and drifting snow past the translucent windows of seal intestines",[1] the extra heat produced by the stimulating effect on the energy output of a high protein diet helps to create comfort in that inhospitable climate. In warmer regions there does not seem to be any good reason for such generous use of protein, when carbohydrate food is everywhere obtainable and much the cheaper and when extra

[1] Macmillan, D. B. "Food Supply of the Smith Sound Eskimos," *American Museum Journal*, March issue, page 172 (1918).

heat production from food frequently means so much more heat to get rid of lest it cause real discomfort. To what extent climate influences the ease with which the kidneys eliminate nitrogenous waste is not known, but there does not seem to be any good reason for putting an unnecessary load upon them, any more than there is for straining one's back to lift a trunk just to see how far one can tax his muscles. We have no easily applied measure of kidney endurance and, inasmuch as their fitness is indispensable to well-being, it would seem common sense to undertax rather than overtax them.

Protein does not exert any marked stimulating effect on heat production when it constitutes a relatively small proportion of the total calories; i. e., not over 10 to 15 per cent. Assuming the average daily energy expenditure of a sedentary man to be 2,500 calories, 10 per cent or 250 calories in the form of protein would be equivalent to 62.5 grams of protein, equal to 0.9 gram of protein per kilogram, while actual requirement is, as we have seen, about 44 grams per day or 0.6 gram per kilogram. Hence, an allowance of 10 per cent of the total calories in this case means 50 per cent more than requirement, which should allow for varying efficiency of proteins of different amino acid make-up, provided some proteins of high efficiency, such as those of milk, eggs, or meat, are included in a digestible mixed diet.[1]

Muscular Work and Protein Requirement

Although it is possible for muscular work to be done

[1] For the contributions to the diet made by different kinds of food see Chapters xi and xii.

exclusively at the expense of protein, what really happens is that the protein so used is first deprived of its nitrogen and thus put on a par, so to speak, with the other fuel foods, carbohydrate and fat. It is as if one should undertake to make a fire with boards full of nails. The boards would burn like any others, but the nails would add nothing to the fire. The early conception of the relation of protein to muscular work was quite erroneous. Liebig, the great pioneer in biochemistry, having discovered the significant fact that protein gives rise to nitrogenous substances which appear in the urine and feces, and having suggested that urea might be a measure of protein metabolism (1840), conceived the idea that in muscular contraction muscle substance was destroyed and could only be replaced by protein—"dead meat and blood must be converted into living flesh and blood." [1]

Before Liebig's death, however, it was shown by Bischoff and Voit (1860) that this view was wrong. They fed meat to dogs under a variety of conditions, collecting and analyzing the urine, and found that the more protein the dog ate the more nitrogen there was in the urine; that it was the character of the diet rather than the amount of muscular work which caused changes in the protein metabolism. This concept was put to the test in 1860 by two of Voit's pupils, Fick and Wislicenus. They undertook to discover just how much protein was used in a strenuous excursion up the Faulhorn, a mountain over 6,000 feet high, and demonstrated conclusively that muscular work is done almost entirely

[1] Cited by Lusk, Graham. Barker's *Endocrinology and Metabolism*, page 48. D. Appleton and Co. (1922).

at the expense of carbohydrate and fat when these are available. Eating only nonnitrogenous food and keeping account of all nitrogen excreted in the mountain adventure, these young men compared the amount of protein metabolized with the work actually done and found that less than half the fuel burned was derived from protein.

Years later a far more accurate experiment of Atwater's showed more clearly the influence of work on nitrogen excretion. Several persons were studied in the respiration calorimeter for many days, first at rest and then at work. In the rest experiments they metabolized 1.51 grams of protein per kilogram; when they worked hard enough to double their heat production they did not raise their nitrogen output at all, as it averaged 1.49 grams per kilogram. Under some circumstances the amount of protein metabolized during muscular activity may be slightly higher than during absolute rest, but if the protein intake amounts to as much as one gram per kilogram, as it usually does in a wholesome mixed diet, any such increase due to muscular exertion is more than covered by an intake which is nearly 100 per cent above requirement. In severe muscular exercise, the foodstuff needed to prevent exhaustion is not protein but carbohydrate.

Henderson and Haggard (page 56) concluded from their study of intense muscular activity in the Yale boat crew that the closer an athlete comes to using carbohydrate as fuel the better his "wind" and the more prolonged his endurance. They observe that "a man can even make an intense exertion although rather disadvantageously, on a combustion almost entirely

of fat from his own body;" nevertheless, "sugar is the best quick fuel for intense exertion."

Section 2

THE ASH CONSTITUENTS AS BUILDING MATERIAL

The mineral elements which are essential components of the human body will be realized better, perhaps, if we make a list showing the approximate amount of each present in the organism:

Mineral Elements in the Human Body

Element	Amount in a 70 kg. man gms.
Calcium	1050
Phosphorus	700
Potassium	245
Sulphur	175
Sodium	105
Chlorine	105
Magnesium	35
Iron	2.8
Iodine	0.028
Fluorine Silicon Manganese	Very minute quantities

Traces of other elements; e. g., boron and arsenic, have been reported but whether or not these are essential to body structure is not clear.

Upon food we depend for a supply of all of these mineral elements, just as we depend upon it for the various amino acids which are built into the body proteins. Pure carbohydrates and fats furnish none. From protein we get not only nitrogen but also sulphur, found as an integral part of the amino acid cystine and one

or two others. Just as proteins vary in their proportion of cystine they vary also in their yield of sulphur, some, such as lactalbumin, being very rich and others, as gelatin, lacking it entirely. Food iron is always combined with protein, although we find it not only in the hematogen of egg yolk and the hemoglobin of blood but also in food materials which we do not usually consider rich in protein, such as the green parts of plants and outer coats of grains. While certain proteins are rich in phosphorus; e. g., the vitellin of egg yolk and the casein of milk; and certain ones yield calcium, the most important being casein, we are not dependent exclusively upon proteins for either phosphorus or calcium.

With the exception of sodium and chlorine, which we get chiefly combined as common table salt (sodium chloride), the mineral elements of the diet are drawn from a great variety of sources and only tables showing the chemical composition of food materials will give satisfactory information in regard to their distribution.[1]

Mineral Elements in Body Structure

Quantitatively the mineral elements most prominent in the body are calcium and phosphorus. They chiefly are responsible for the rigidity of the bones and teeth. In bones with marrow, the mineral matter is about two-fifths of the total dry weight; in bones without marrow, about three-fifths; and of this total mineral content about 85 per cent is calcium phosphate and 10 per cent calcium carbonate. Altogether, approxi-

[1] See Appendix, Table I; also Sherman, H. C. *Chemistry of Food and Nutrition*, Appendix B, Tables II and III; and Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition, pages 133–143.

mately 99 per cent of the total calcium and 90 per cent of the total phosphorus of the body are in the skeletal tissues, and serve to maintain the framework whose value we most appreciate when we see the effect on health and beauty of poor teeth or of a disease like rickets, in which the mineral deficiency of the bones may result in a hollow chest and poorly developed lungs, to say nothing of the unattractiveness of bowlegs, knock-knees or flat feet.

The structure and the functions of the human body cannot be well understood without appreciation of the fact that the cell, a microscopic mass of protoplasm, is a unit endowed with all the attributes of life.[1] The egg cell divides into two daughter cells, which in turn divide each into two others, until there are finally billions and billions of cells, differentiated in the process of development for various functions; some for building skeleton, others for nerves, others for the digestive system, etc. In a cubic inch of normal human blood there are said to be as many as 70 billion cells, red and white, all equipped for special chemical work.

The life of the cell is governed by a minute but highly organized mass of protoplasm called the nucleus. It consists of a net-like framework whose meshes are filled with a special kind of protein called nucleoprotein and whose threads entangle granules of chromatin, consisting of highly complex proteins containing iron. Upon the integrity and the efficiency of the chromatin substance of the nucleus depend the nutrition, growth, and reproduction of the cell and hence the very life of

[1] For an adequate description of the cell and its relation to body structure as a whole, recourse must be had to standard works on biology.

the organism as a whole. A diminution or withdrawal of the supply of iron, therefore, interferes with fundamental nutritional processes.

The proteins of the cell nucleus, nucleoproteins, are distinguished by the fact that they contain phosphorus as an integral part of their structure; hence phosphorus, like iron, is intimately associated with the fundamental processes of nutrition, sharing in the control of cell activities.

The body of the cell, the cytoplasm as it is called, contains, in addition to protein, mineral salts and water, another substance called lecithin, allied to the fats but having phosphorus as an indispensable element in its composition. Lecithin helps the cell to connect with its environment, to absorb nourishment, eliminate waste or discharge some product of its own manufacture for the benefit of other parts of the organism.

Among cells differentiated for special function are the red corpuscles of the blood, which are the carriers of oxygen to all the tissues and the removers of carbon dioxide arising from the combustion of body fuel. Their power to transport these gases depends upon an iron-bearing protein, hemoglobin, and any serious diminution in its amount is accompanied by increased respiration and accelerated heart action in an effort to compensate for the lessened carrying capacity of the blood. It is just as if a chain pump which could easily deliver a certain amount of water per second if the handle went up and down once every half minute had half its buckets removed. Then to make the same water delivery the pump handle would have to go up and down twice as often.

Phosphorus and iron are as essential to every living cell as nitrogen. On this point we may quote two authorities on the metabolism of these elements. Forbes, the successor of Armsby as director of the Animal Nutrition Laboratory at the Pennsylvania State College, says in regard to phosphorus: "Among the several inorganic elements involved in animal life phosphorus is of especial interest. No other one enters into such a diversity of compounds and plays an important part in so many functions. Structurally, it is important as a constituent of every cell nucleus and so of all cellular structure; it is also prominent in the skeleton, in milk, in sexual elements, glandular tissue and the nervous system." [1] And Sherman, to whose own researches upon iron our knowledge of iron requirement largely rests, says in regard to this element: "Iron stands in the closest possible relation to the fundamental processes of nutrition, being an essential constituent both of the oxygen-carrying constituents of the blood and of the substances which appear to control the most important activities within the cell." [2]

The other mineral elements are found variously distributed in the body, chlorine occurring chiefly in the gastric juice; sodium in the blood and other fluids, combined with chlorine as sodium chloride (common salt); potassium, most abundantly in the protoplasm of muscles and various organs; magnesium, chiefly in the

[1] Forbes, E. B., and Keith, H. M. *A Review of the Literature of Phosphorus Compounds in Animal Metabolism*, page 11. Ohio Agricultural Experiment Station, Tech. Bull. No. 5 (1915).

[2] Sherman, H. C. *Iron in Food and Nutrition*, page 7. U. S. Department of Agriculture. Office of Experiment Stations, Bulletin No. 185 (1907).

bones but also in muscles and a little in blood; fluorine, in bones and teeth; iodine, in the thyroid gland and its product, thyroxin. While these elements contribute to the composition of the body, they function more prominently in the regulation of body processes and these regulatory functions will be discussed in Chapter VIII.

Section 3

WATER AS BUILDING MATERIAL

When a rubber water bottle is full of water, one is quite well aware that the water is there, even though the stopper holds every drop inside and the outside is

Fig. 35.—A Half-Pound Potato Contains Nearly a Tumblerful of Water.

perfectly dry; but how many realize that a potato skin, neatly incasing the useful tuber in a dry covering, also holds water like the rubber bottle? We do not realize the water in the potato as we do in the bottle because it is held in the cells; but when we break the

cell walls, as in grating a raw potato, we can squeeze out a surprising amount. It is the same with the body of a man. Muscles, liver, and kidney hold as much water in proportion to their weight as does the potato; brain tissue holds more; and even bone, proverbially dry, is more than one-third water. Altogether two-thirds of the adult human body is water.

Water is essential to the constitution of protoplasm. No cell functions when it is absolutely dry, and most cells must be constantly bathed with fluid, in order to do their work. Furthermore, the cells depend upon having their food transported to them by the water route (the blood), a demand which alone requires about ten pounds of water constantly in circulation. The cells also depend upon having their waste products flushed away, so there must be waste-bearing water (urine) while there is life. The surface of the lungs must be kept moist or there can be no intake of oxygen or riddance of carbon dioxide.

Water is so commonly taken in response to the feelings of thirst that we ordinarily think little about our water supply, save to be sure that it is sanitary and refreshing. But we also get more or less water in food, as even the driest cracker is not absolutely water-free. The amounts in some common foods are indicated in the chart on page 154.

A certain amount of water is produced within the body by the combustion of the fuel foods. A similar production of water may easily be demonstrated by setting a cold flat iron on a gas burner. Before the flame has had time to warm the iron the water of combustion from the burning gas condenses on the iron,

often making it perceptibly wet. Later on, the heat of the iron converts the water into vapor and it is no longer perceived. So in the body, the oxidation of 100 grams of fat results in the production of 107 grams of water, and the oxidation of 100 grams of protein, of 41 grams of water. Benedict calculated that Levanzin, the subject of the thirty-one day fast, produced on the twenty-first day by combustion of his own body substance 341 grams of water.[1] This metabolic water is

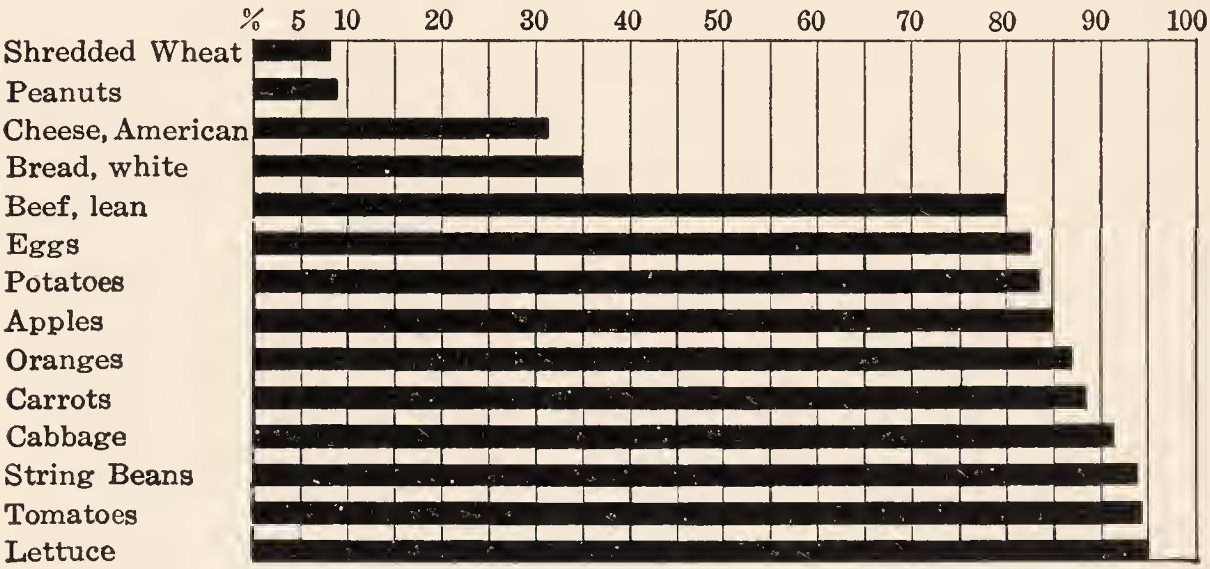


FIG. 36.—Relative Amounts of Water in some common Food Materials.

useful for the distribution of nutrients, making changes in concentration within the cell which facilitate movement of substances into the cell.

Many varieties of insect have nearly all their water needs met by this metabolic water, subsisting on food containing less than 10 per cent of water and never taking a drink. For animals in hibernation, it is sufficient for several months. The dog requires no other water if he eats plenty of meat. Dogs have not as high water loss as man because they do not perspire.

[1] Benedict, F. G. *Study of Prolonged Fasting*. Carnegie Institution of Washington, Publication No. 203, page 412 (1915).

DuBois finds the average loss of water from lungs and skin in the normal resting man to be 680 grams per day, if the temperature is 23° C. (73.4° F.) and the humidity medium. Benedict and Milner account for the water intake and output of a man for a day as follows: [1]

Intake		Output	
Drink	1,950.00 grams	Feces	191.30 grams
Food	2,972.43 "	Urine	1,089.20 "
		Respiration and perspiration	2,929.73 "
	4,922.43 grams		5,210.23 grams

The water content of the body is subject to considerable fluctuation. Benedict and Joslin report [2] a marathon runner who lost 8.5 pounds in three hours and a football player who lost 14 pounds in one hour and ten minutes, of which 13.75 pounds were calculated to be water. Not only "sweating out" but also certain changes in diet affect the water content of the body; for example, when the body changes from a strictly carbohydrate diet to one of fat or protein exclusively there is a considerable loss of water which will be gained upon resumption of the carbohydrate diet. Thus Benedict and Milner [1] in a six-day experiment gave first for three days a diet having 66 per cent of its calories in the form of carbohydrate. On this the subject gained 165 grams of water, but part of this replaced other body substance, as the weight gain was only 61 grams.

[1] Benedict, F. G., and Milner, F. D. *Experiments on the Metabolism of Matter and Energy in the Human Body.* Office of Experiment Stations, United States Department of Agriculture, Bulletin No. 175, page 163 (1903–4).

[2] Benedict, F. G., and Joslin, E. P. *A Study of Metabolism in Severe Diabetes.* Carnegie Institution of Washington, Publication No. 176, page 96 (1912).

There are, then, three important sources of body water:

(1) Water taken as a beverage or in other liquids.

(2) Water contained in solid foods, especially fruits and vegetables.

(3) Water formed in the tissues in combustion of the fuel foods.

The normal avenues for water loss are the skin, the respiratory passages, the alimentary tract and the kidneys. Any considerable loss or storage of water usually results in a change in body weight. But in undernutrition water may be stored in the tissues in place of fat, and conversely, in obesity fat may replace water. Hence an underweight may increase his food intake with real advantage even though there be no visible gain in weight at first; and an obese person may be disappointed that reduction in food intake does not bring about an immediate loss of weight, owing to the replacement of any body fat burned by water.

In health the water balance is easily maintained by a liberal water intake. In disease the disturbance of the water equilibrium may be serious and call for special measures to bring about normal conditions. The rôle of water in the regulation of body processes will be discussed in Chapter VIII.

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CHAPTER VIII

FOOD AS REGULATING MATERIAL—THE ASH CONSTITUENTS AND WATER

For the purposes of the present chapter we may advantageously picture the cells of the body as the citizens of a great metropolis. As individuals, each has a private independent life of his own; yet each life is modified by sharing in the activities of some group. Just as citizens come together to work in the same shop or to participate in the enterprises of some club, so cells are massed in tissues and organs to perform some special service impossible to one alone. Furthermore, in addition to individual and group activities, all share in the larger life of the whole. And just as citizens all over a city use the same water and gas mains, the same electric wires for light and telephone, and the same mail service, so cells all over the body derive nutriment from the common blood stream and receive oxygen by means of the same respiratory system. In either case individuals, and even large groups, may never meet one another; yet the community life is maintained through "regulations" which direct their actions and prevent one individual or group from prospering at the expense of others, or the aggregate doing injury to any one portion.

There are found in the body certain substances which figure prominently in the coördination of the functions of nerves, glands, muscles, etc., and enable

it to use its available fuel and building material to the best advantage. These regulating substances may be grouped in three main divisions: ash constituents, water, and vitamins. Ash constituents and water will be discussed in this chapter and vitamins in the next.

Section I

ASH CONSTITUENTS AS REGULATORS OF BODY PROCESSES

Some Ways in which Mineral Elements Function

We have already seen that chemical elements which may enter into the structure of the body in very minute quantities are highly important for the maintenance and growth of the cells. In the regulation of body processes, the amount of an element present in the organism gives no clue as to its significance in the coördination of cell functions. Each element has its own special part to play; two which may be closely related chemically cannot exchange places and may in some of their functions be actually antagonistic to each other. Inasmuch as the rôle of the mineral salts in vital processes is a matter of their physicochemical relationships, any detailed discussion of their functions leads far into the fields of chemistry and physics, and is beyond the scope of this book. No attempt will be made to do more than discuss briefly some of the more obvious ways in which the ash constituents aid in the regulation of body processes.

In the first place, ash constituents influence the contractility of muscles. If a muscle is removed from the body and put into a solution containing a suitable

mixture of pure salts (particularly calcium, sodium and potassium chlorides) it will, when stimulated, contract as it would in the body. But if it is put into distilled water (which contains no such salts) it will not respond when stimulated. Again, if the muscle is put into a solution containing the sodium and potassium mentioned above, but not the calcium, it will fail to respond; but when calcium is again added in suitable amount to the solution it will respond as at first. Thus the dependence of the muscle upon calcium may be demonstrated in the laboratory. It may also be demonstrated by the use of a frog's heart, which can be made to beat or stop as calcium is present or absent from a solution in which the organ has been suspended. So we say the muscles of the heart depend for their rhythmic beat upon the nature of the salts in the fluids which bathe them.

In the second place, ash constituents determine the irritability of nerves. Just as a muscle will not contract normally if suspended in distilled water, so a nerve similarly placed will fail to respond to any stimulus, but when bathed with a suitable salt solution will behave in the normal manner. All the organs regulated by the central nervous system depend for the integrity of their functions not only upon the presence of calcium, potassium, and sodium in the fluids within the nerve tissues, but upon their presence there in just the right proportions.

In the third place, ash constituents control the movement of liquids in the body. Digested food materials must pass freely from the intestine into the blood stream without any blood passing back into the intestines.

Also, liquids must pass from the blood into the various organs and tissues, and such a fluid as the gastric juice must be derived from the blood and poured into the stomach. Furthermore, the waste matter of the cells taken away by the blood must be withdrawn from it by the kidneys and discharged in the watery solution which we call urine. It is due to interactions between mineral elements that the cells can bring these things to pass.

Another function of ash constituents is to assist in the coagulation of the blood. Any wound, however slight, would threaten death by bleeding had we not this interesting protective mechanism, whose value we appreciate only when we learn of certain persons known as "bleeders," whose blood does not readily clot, even after a pin prick. Calcium is an important factor in the coagulation process.

The ash constituents are essential also to the digestive processes. For example, in the stomach, the gastric juice owes its characteristic acidity to hydrochloric acid, upon which the activity of pepsin in digestion depends. In the small intestine, other mineral salts make the secretions alkaline, favoring the digestive processes there, especially the digestion of fat.

Another important function is to keep the blood neutral—neither acid nor alkaline. Here phosphorus (as phosphoric acid) and sodium (as bicarbonate) act as buffers, which means that, when they are present in a solution, considerable amounts of acid or alkali may be added without showing any effect, for they change so as to dispose of the acid or alkali as such and keep the solution neutral. The situation is somewhat like that of two children of unequal weight at each end

of a teeter; they solve the difficulty of not being able to move up and down on account of their weight inequality by placing a third child in the middle to serve as a buffer; i. e., to move first toward one child and than toward the other, thus adding his weight where it is needed at the moment.

Ash constituents take part in the transport of oxygen from the lungs to the tissues and of carbon dioxide from the tissues to the lungs which alone makes possible the continued combustion of fuel foods. The power of the iron-bearing hemoglobin of the blood to combine under certain conditions with oxygen and under other conditions with carbon dioxide is fundamental to the process of respiration.

As the ash constituents enter into the composition of every living cell, they determine the vital processes of oxidation, secretion, development, and reproduction. Phosphorus and iron, indispensable to every active cell, as shown in Chapter VII, are outstanding examples of such controlling elements.

Mineral elements are essential to the structure of certain complex chemical compounds which profoundly influence the course of metabolism. A conspicuous example is iodine, an element found only in the thyroid gland and its product thyroxin, which have been referred to in Chapter IV as profoundly influencing the energy metabolism. But this is not all. Without iodine for the proper functioning of the thyroid, normal growth in the young and the maintenance of the tissues in a state of health in the adult are impossible. The influence on development is strikingly shown in the case of tadpoles; ordinarily they require three weeks

to change into frogs; given thyroid, the metamorphosis begins in a few days and is completed so rapidly that there is no time for growth in substance along with the loss of tail and formation of legs, so that the result is pygmy frogs. In the human adult loss of thyroid function results in changes in skin, hair, facial contours, and other signs that a controlling mechanism is out of order.

Requirements for Ash Constituents

The body is constantly losing some of each mineral element. It becomes necessary to replace the loss through diet or the body will not be maintained in health. For the adult, whose tissues are fully formed, it is only necessary to make good the "wear and tear"; for the growing organism there must be, as in the case of protein, an additional "growth quota" to insure the construction of new body substance at a proper rate.

In order to administer the diet intelligently, we need to know as much as possible about the requirements for various mineral elements, both in childhood and adult life. For some elements, as calcium and phosphorus, the amount needed daily is relatively large, and on this account there is possibility of serious shortage unless food is chosen with discrimination; for others, as iron, the portion needed day by day is very minute, but the quantities in food materials are also minute, and an intake below the optimum is likely to occur if the matter be left entirely to chance. Practically we shall find that if the requirements for calcium, phosphorus, and iron (in some regions iodine) are definitely met there is little likelihood of the other mineral elements being inadequately furnished, since

the foods which supply the former will at the same time provide many of the latter.

The Requirement for Phosphorus

Phosphorus is indispensable in all active tissues of the body, being concerned in cell multiplication and cell movement and the maintenance of proper liquid content of the tissues. It also plays an important part in regulating the neutrality of the blood and is in some way a factor in the chemical changes through which carbohydrates are oxidized and their energy liberated at just the rate demanded by the needs of the organism.

Phosphorus leaves the body partly in the urine and partly in the feces; the relative amount leaving by each path largely depends on the composition of the diet. When food rich in calcium is eaten, more phosphorus is excreted through the feces than when little calcium has been taken. Sherman, as a result of extensive work in his own and other laboratories on the phosphorus requirement of adults, says: "We are probably justified in concluding that we now know the phosphorus requirement with about the same probable accuracy that the protein requirement is known, and that about one-fortieth to one-fiftieth as much phosphorus as of protein is required in the maintenance metabolism of man."[1] This gives for the adult an average of 0.88 gram per 70 kilograms of body weight.

Since it is impossible to estimate individual requirement with absolute precision under ordinary living conditions, and equally impossible without laboratory

[1] Sherman, H. C. "Phosphorus Requirement of Maintenance in Man," *Journal of Biological Chemistry*, Vol. 41, page 173 (1920).

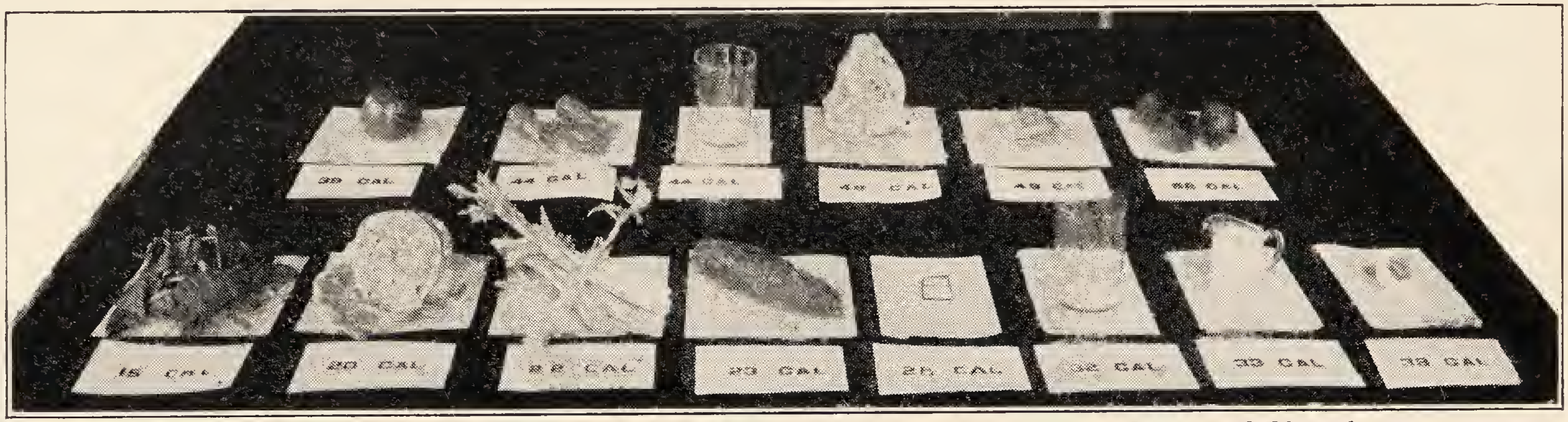

FIG. 37.—Amounts of Some Common Foods Required to Yield 0.044 Grams of Phosphorus.

Upper Row, left to right	*Grams*	*Calories*
Tomatoes	172	39
Carrots	96	44
Beans, lima, dried	13	44
Cabbage	151	48
Shredded wheat	14	49
Beets	114	52

Lower Row, left to right	*Grams*	*Calories*
Spinach	65	15
Lettuce	103	20
Celery	118	22
Cucumber	132	23
Cheese, American	6	28
Beans, navy, dried	9	32
Milk, whole	48	33
Egg	24	36

experiments to estimate intake exactly, the amounts in food being subject to considerable fluctuation, it is only prudent to set a practical dietary standard considerably higher than the actual amount needed for maintenance. It seems very moderate to add 50 per cent as a "contingency fund" or "factor of safety." This would make a dietary standard of 1.32 grams of phosphorus per man per day, equivalent to 0.019 gram per kilogram of body weight.

The Phosphorus Requirement of Children

Because phosphorus is essential to all body tissues, the growth of new body substance involves the retention of a certain amount, just as we have already seen it to require a storage of protein. The greater part of the phosphorus retained is deposited in the bones along with calcium, as calcium phosphate. If conditions are not favorable for the deposition of calcium phosphate in the bones, we have the disease known as rickets, which will be discussed in detail later. One of the notable advances in the study of rickets was the observation that it is characterized by a low phosphorus content of the blood. After that it was demonstrated that rickets could be produced experimentally by feeding a diet low in phosphorus. Thus the importance of this element in the diet of the young received additional emphasis. An extensive study of the phosphorus requirement of children has been made by Sherman and Hawley.[1] They took

[1] Sherman, H. C., and Hawley, E. "Calcium and Phosphorus Metabolism in Childhood." *Journal of Biological Chemistry*, Vol. 53, page 375 (1922). See, also, Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, pages 313–316. The Macmillan Co. (1926).

twelve children ranging in age from three to thirteen years to a country home for convalescent mothers, where they could be supervised day and night, and kept account of all food eaten and of all excreta. Some of the children were under this close observation as long as 84 days. From analysis of the data so collected, Sherman says: "It was found that optimum storage of phosphorus in the growing children of three to thirteen years of age was not obtained until the intake reached from 1.16 to 1.46 grams of phosphorus per child per day, thus indicating that the child needs for optimum growth about one and one-half times as much phosphorus as is needed by a full-grown man for maintenance." [1] As a result of this thoroughgoing investigation, it seems wise to set the dietary standard for phosphorus at one gram per day for children up to the age of fourteen, and thereafter to allow at least as much per 100 calories as for a full-grown adult.

The Requirement for Calcium

The rôle of calcium as body-building material is obvious and striking. The rigidity of the bony framework of the body is in such contrast to the softness of other tissues and is so clearly related to the presence of calcium in the bone that every one is impressed. Not so readily apparent, but of even greater significance, is the part played by this element in the regulation of body processes. Some of the ways in which it functions have already been mentioned in discussing the general functions of ash constituents: viz., the control of

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 318. The Macmillan Co. (1926).

the contractility of muscles, and particularly the rhythmic beat of the heart; the preservation of the normal response of nervous tissue to stimuli; and the coagulating power of the blood. In addition to these very important functions, calcium is a kind of coördinator among the mineral elements. As has already been said, these must be nicely balanced in order that all parts of the body may function successfully; if sodium, or potassium, or magnesium, for instance, should tend to be too much in the ascendency, calcium is capable of correcting the disturbance which they might make, whether it be in the direction of increased or decreased irritability. Calcium also seems to foster the retention of iron in the body, as it is possible to maintain iron equilibrium on a smaller amount when calcium is abundant. Altogether, it is highly important that the organism have at all times an adequate supply of this element.

In adults, the bones become to some extent a reservoir of calcium, which can be drawn upon to replenish the soft tissues and fluids, with no damage to the bone other than the weakening consequent to withdrawal of some of the supporting calcium phosphate. But in the young there must be a liberal supply of calcium for the developing bone itself; any deficiency in the calcium supply, or any disturbance of the conditions under which the bone is able to store calcium, results in weakened bones, contracted thorax and pelvis, and otherwise stunted growth.

The calcium requirement must be studied by taking account of calcium in food, urine, and feces, in carefully planned experiments. Ninety-seven experiments of

FIG. 38.—This rat was placed at the age of four weeks on a diet containing about half the normal amount of calcium. It then weighed 28 grams. It was able to survive for twenty-five weeks when it died weighing 42 grams. A normal rat at the age of twenty-five weeks weighs about 160 grams. Note the distortion of the spinal column in the thoracic region, and especially the diminished space for the lungs on the right side of the picture. When the animal was autopsied, the lungs were so contracted on this side that they expanded like a sponge when released from it.

this sort, analyzed by Sherman, indicate that the calcium requirement of adults is about 0.45 gram of calcium per day. As in the case of phosphorus, there should be a "safety allowance" of at least 50 per cent more, making a dietary standard of 0.68 gram per man per day or 0.097 gram per kilogram of body weight.

The calcium requirement of women is greatly increased by pregnancy and lactation. During pregnancy the mother must provide a store of calcium upon which the fetus draws for the development of its skeleton. Lusk cites a study of the calcium retention of a mother and child for 23 weeks in which it was found that the mother retained only 4.2 grams, but the fetus retained 30.12 grams, or more than seven times as much. The weekly additions to the calcium of the fetus at different periods were as follows: [1]

Week of Pregnancy	Calcium Added per Week Grams
16	0.41
21	0.43
29	2.09
40	2.09

Estimating the mother's ordinary requirement for herself as about 4 grams per week, the addition of 2 grams per week for the fetus would mean a 50 per cent increase in the requirement of the pregnant woman, so that she should have at least three-quarters of a gram of calcium per day during the second half of the gestation period, if she is to be fully protected against withdrawal of calcium from her bones and teeth.

[1] Lusk, Graham. *Science of Nutrition*, 3d edition, page 390. W. B. Saunders Co. (1917).

In lactation the increased demand for calcium must be proportional to the amount of milk consumed by the baby. For a child of average weight, making normal growth, it may be estimated that the milk consumed will yield calcium in approximately the following amounts:

WEEKLY CALCIUM CONSUMPTION OF INFANTS

Age Months	Calcium in Milk Grams per Week
3	1.9–2.2
6	2.5–2.7
9	2.7–3.0

It thus appears that no less is needed in the early months of lactation than in the last weeks of pregnancy, and that the demand upon the mother in the later months of lactation will raise her total calcium requirement to at least one gram of calcium per day, a need best met by a quart of milk daily.

The Calcium Requirement of Children

In view of the high constructive and regulatory functions of calcium, it is important that the growing organism be at all times liberally supplied with this element. The serious handicap of calcium shortage during the period of growth is readily demonstrated in experimental animals. The two rats in the photograph on page 172 were of the same litter, weaned from a mother on a normal diet at the age of four weeks and then put, one on a normal diet, the other on a diet adequate in all respects save in the quantity of calcium.

The difference in the rate of growth will be best appreciated from the weight records; the animal on

the normal diet at the age of 16 weeks weighed three times as much as the animal deprived of calcium. The animal on the low calcium diet was not only smaller and weaker than its brother on a normal diet, but its fur was rough and thin and it suffered from nasal hemorrhages in addition to skeletal deformities.

That the results of a shortage of calcium are quite different from those of a shortage of protein is well exemplified by the comparison of this rat on the low

FIG. 39.—Low Calcium Diet. Normal Diet.

These rats are both the same age (16 weeks). The one on the normal diet weighs 216 grams; the one on the low calcium diet 60 grams. Note the inability of the rat on the low calcium diet to stand on its fore feet, and also the distortion of the posterior part of the body.

calcium diet with one on a low protein diet shown in Fig. 40. While both are stunted to the same degree, the low protein diet permitted more growth of the skeleton and interfered less with health, so that the animal on this diet is sleek and slim in contrast to the short, stocky, bushy rat on the low calcium diet.

Such experiments impress upon us the importance of calcium for the growing child. During the period of growth, a white rat, which will have multiplied its birth weight about 70 times when fully mature, will in-

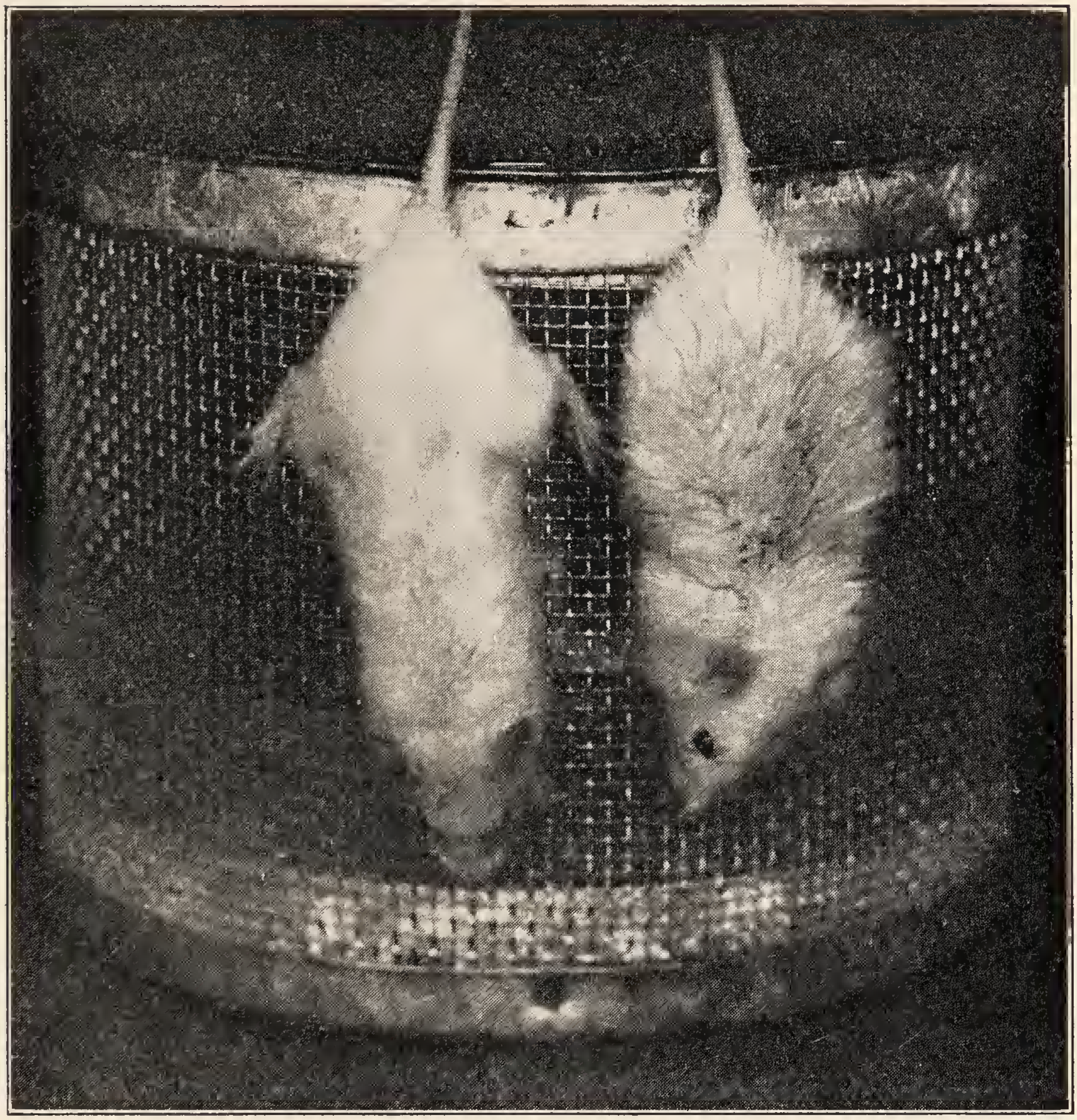

FIG. 40.—Two rats placed at four weeks of age on restricted diets and photographed at the age of sixteen weeks. The one on the left had only half enough protein, the one on the right only half enough calcium. Both weigh the same (60 grams). The control on an adequate diet shown in Fig. 39 weighed 216 grams at this time. Note the short, smooth fur and slender form of the low-protein rat, and the long, bushy fur and very short body of the low-calcium rat.

crease the phosphorus content of its body about 150 times and the calcium content 340 times.[1] Such figures bear ample testimony to the need for a liberal supply of calcium during the whole period of growth.

In the case of children, we are now fortunate in having a very remarkable study of calcium requirement

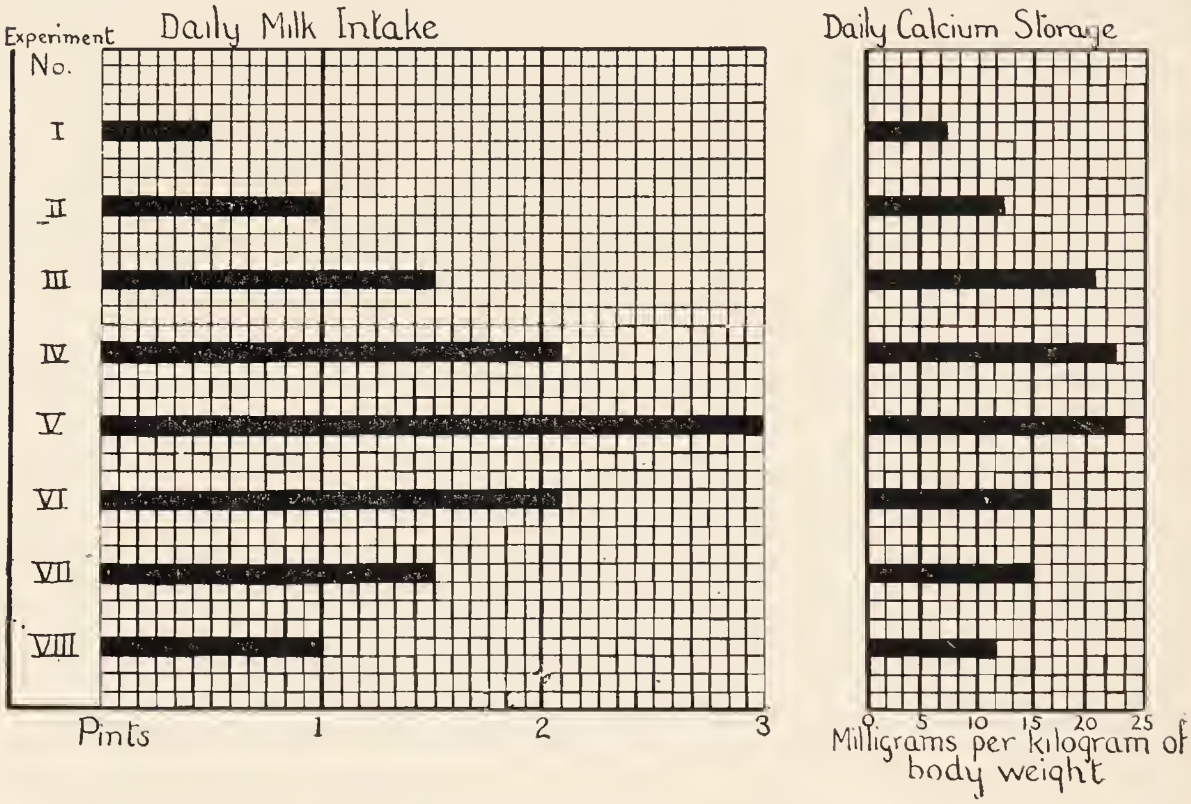

FIG. 41.—This chart shows a series of 8 experiments of 6 days each in which the calcium intake was systematically varied from period to period by changes in the amount of milk. The very definite response to increased milk intake is shown in the record of calcium storage of one of the children, a 12-year-old girl.

by Sherman and Hawley. Altogether 417 experiments were conducted on 21 healthy children from 3 to 14 years of age. In one series, on three children, 4, 5 and 12 years of age respectively, extending over 48 days, the calcium was kept at different levels in successive periods by changing the amount of milk in the

[1] Sherman, H. C., and Quinn, E. J. "The Phosphorus Content of the Body in Relation to Age, Growth, and Food." *Journal of Biological Chemistry*, Vol. 67, page 667 (1926).

diet, in order to find out what daily allowance of milk would induce the best calcium storage. In the case of all three children the best utilization of calcium was found when approximately a quart of milk a day was included in a simple mixed diet. The relationship between the milk and the calcium storage is shown in Fig. 41.

"When the food intake included 1,000 gm. of milk per day, the other foods of the mixed diet being taken *ad libitum*, the daily intake of calcium by these normally growing children of 4 to 12 years averaged 0.053 gm. of calcium per kilo of body weight, and of this intake approximately one-third was retained in the growing body." [1]

In another series of experiments, vegetable foods were substituted for half of the milk, in quantities to yield the same amount of calcium as the milk which they displaced, but in no case did the children reap the same benefit from the calcium of vegetables that they did from the calcium of milk.

The authors conclude that "for children of all ages from 3 to 13 years, inclusive, an average intake of not less than one gram of calcium per day (about twice as much as the maintenance requirement of an average man) is needed to support an optimum rate of storage in the normally growing child. But the experiments also show that better storage resulted when the calcium was furnished mainly in the form of milk, than when one-half of the milk was replaced by vegetables of equal calcium content, even though the vegetables were

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 314. The Macmillan Co. (1926).

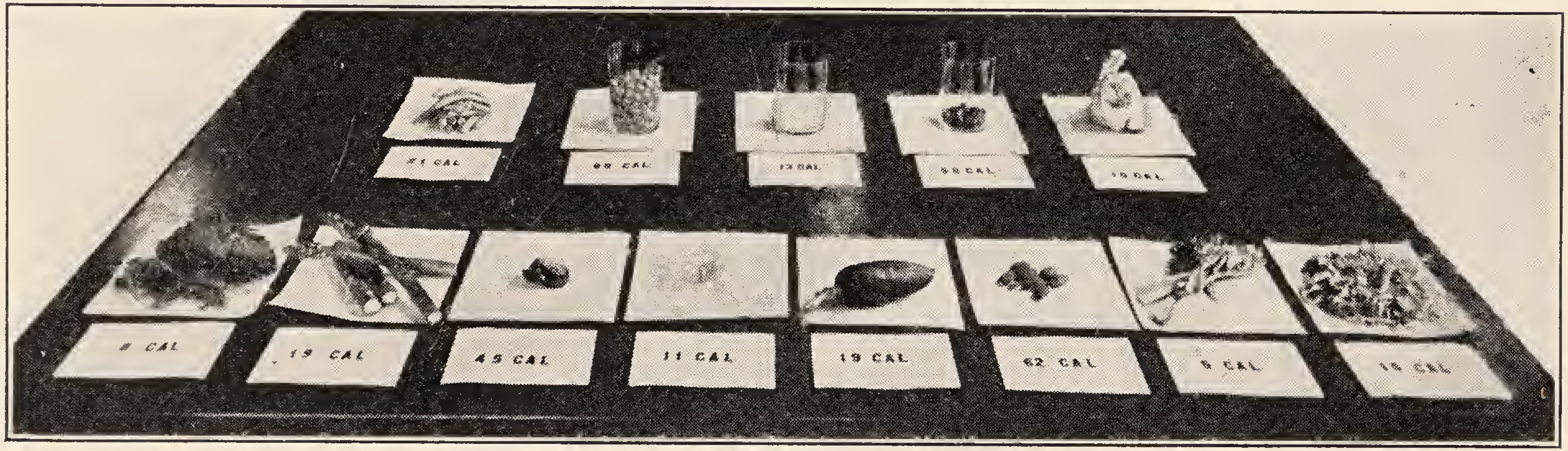

Fig. 42.—Amounts of Some Common Foods Required to Yield 0.023 Grams of Calcium.

Upper Row, left to right	*Grams*	*Calories*
String beans	50	21
Peas, fresh	88	88
Milk, whole	19	13
Beans, kidney, dried	17	58
Lettuce	54	10

Lower Row, left to right	*Grams*	*Calories*
Spinach	34	8
Asparagus	85	19
Fig	14	45
Cheese, American	3	11
Carrot	41	19
Almonds	10	62
Celery	30	5
Cabbage	51	16

selected and prepared with the greatest care to make them as suitable and as acceptable to the children as possible. Hence it seems better to state the optimum intake not as such a weight of calcium, merely, but as a diet containing a full quart of milk per day together with other foods suitable to the age of the child. Such a dietary will practically always contain 1.0 gram or more of calcium and a proportionately liberal amount of phosphorus, as well as an excellent protein and vitamin content." [1]

The Requirement for Iron

Long before the importance of calcium and phosphorus in vital processes was fully apprehended, the connection between iron in the blood and the oxidative processes in the body had been discovered. Lavoisier made the mistake of thinking that oxidation took place in the lungs, but before his death a mathematician, Lagrange, considering that the temperature of the lungs was not higher than that of the rest of the body, expressed the conviction that oxygen "dissolved" in the blood and that heat might be generated wherever the blood carried the oxygen. It was not until 1838, however, that the Swedish chemist, Berzelius, showed that the red coloring matter of blood was capable of absorbing much oxygen and concluded that this was due to the iron in this pigment. We now know that we have in the human body about 5 million times a million red blood corpuscles, owing their color to the iron-bearing protein, hemoglobin, and through its

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, pages 315–316. The Macmillan Co. (1926).

agency transporting oxygen through all the intricacies of arteries and capillaries to the innermost cells of every organ and tissue.

Not only in the red blood corpuscles, but very generally in active cells, both animal and vegetable, we find iron as an essential part of the cell structure and functioning as a stimulator of the vital processes of the cell. Therefore, as a carrier of oxygen and as an activator of cell functions, iron has significance out of all proportion to the amount in the body—less than one-tenth of an ounce, or the weight of a cent.

Notwithstanding its great prominence in vital activities, there is little reserve store of iron in the body and the amount present in different food sources is also relatively small. Hence we live a kind of hand-to-mouth existence so far as this element is concerned and it becomes important indeed that there be an adequate daily supply and favorable conditions for its utilization.

We now have tables giving the amount of iron in many common food materials,[1] but there has been much discussion of the relative merits of these different sources of iron, and of iron in medicinal forms. The experimental evidence has led to the conclusion that such food materials as green vegetables, egg yolk and liver are more useful in building hemoglobin than medicinal iron, and that medicinal iron is more serviceable when administered along with food iron. In 1900 Professor Emil Abderhalden of Berlin demonstrated that an animal kept for a long time on a diet of milk alone developed anemia, and that the addition of inorganic

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, Appendix B, Tables II and III. The Macmillan Co. (1926). Also Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition, Tables XXVI and XXVII. The Macmillan Co. (1921).

iron to the diet did not improve matters, so he concluded that some other building material was necessary beside iron and an adequate amino acid assortment from proteins of good quality.

In 1925 Hart and Steenbock [1] found, like Abderhalden, that when rabbits had been made anemic by feeding milk as the sole source of iron the addition of inorganic iron did not remedy the anemia, although the animals were able to make good growth for some time. When cabbage was fed as a supplement to the milk the animals often escaped anemia or were slow in developing it; but when milk, inorganic iron, and cabbage were all fed together there was never any tendency toward anemia. What was there in the cabbage to make the difference? To answer this question, an extract of the cabbage was prepared which was practically free from iron. This extract fed with the milk and iron prevented anemia.

It thus became clear that something in the vegetable tissue enabled the organism to link up the milk and the iron and form hemoglobin. Following a suggestion already made by others that this connecting link might be the green coloring matter of the plant tissue, chlorophyll, the Wisconsin investigators fed milk plus iron plus chlorophyll which contained no iron, with the same results as when the cabbage extract was fed. Evidently something not iron needed to be added to milk in order to make hemoglobin, and that could be obtained not only from cabbage, they found, but also from yellow

[1] Hart, E. B., Steenbock, H., Elvehjem, C. A., and Waddell, J. "Iron in Nutrition. I. Nutritional Anemia on Whole Milk Diets and the Utilization of Inorganic Iron in Hemoglobin Building." *Journal of Biological Chemistry*, Vol. 65, page 67 (1925).

corn. Such laboratory findings enable us to interpret the often observed anemia when infants are fed milk alone for long periods, and the improvement when egg yolk or green vegetables are given with the milk. The milk is not to be taken away, as its iron is very efficiently used by the body, but is to be supplemented by those foods which will furnish certain complex chemical groupings needed for hemoglobin formation with which milk is not liberally supplied, as well as additional iron.

As a result of extensive studies of the influence of various foods on hemoglobin and red cell regeneration after severe anemia induced by bleeding, Drs. G. H. Whipple and F. S. Robschiet-Robbins[1] of the University of Rochester School of Medicine and Dentistry, found that feeding of beef liver brought about a very remarkable increase in both hemoglobin and red cells. They believe that the body stores in the liver important substances for the construction of blood pigment. Their work gave further emphasis to the importance of food factors in the control of anemia and suggested the trial of liver feeding in pernicious anemia, a disease for which no cure had ever been found. With liver feeding the results have been truly remarkable. Drs. G. R. Minot and W. P. Murphy[2] of the Peter Bent Brigham Hospital have reported a series of 45 patients on a special diet in which liver was a prominent feature, along with an abundance of fruit and fresh vegetables. Muscle meat was also included, although this has been shown to have

[1] Whipple, G. H., and Robscheit-Robbins, F. S. "Blood Regeneration in Severe Anemia. II. Favorable Influence of Liver, Heart and Skeletal Muscle in Diet." *American Journal of Physiology*, Vol. 72, page 408 (1925).

[2] Minot, G. R. and Murphy, W. P. "Treatment of Pernicious Anemia by a Special Diet." *Journal of the American Medical Association*, Vol. 87, page 470 (1926).

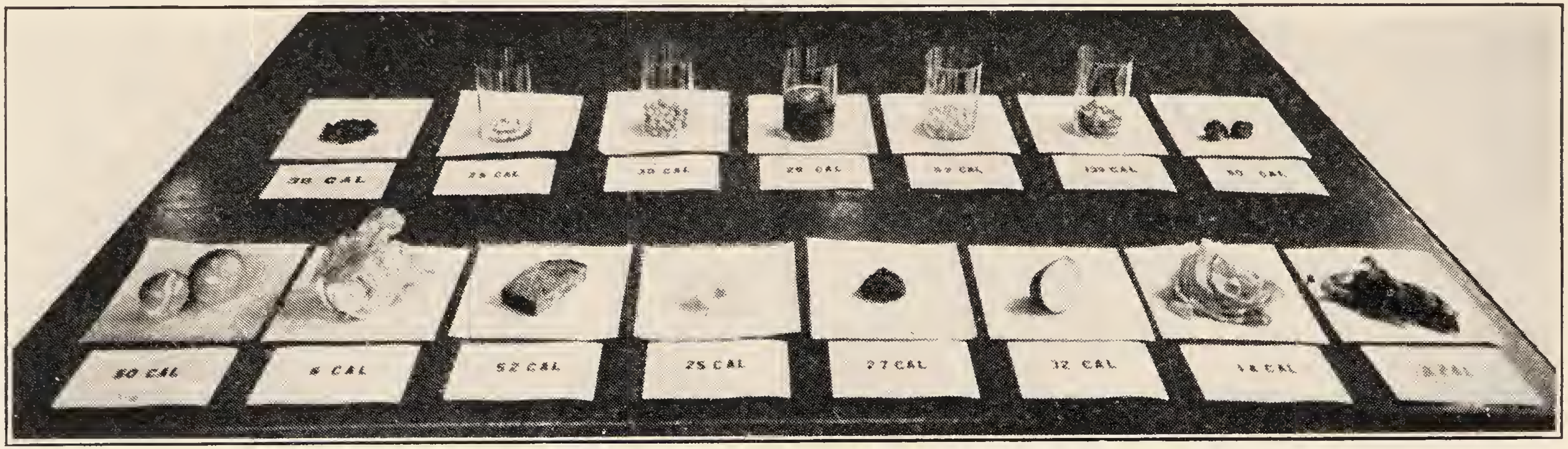

FIG. 43.—Amounts of Some Common Foods Required to Yield 0.0005 Grams of Iron.

Upper Row, left to right	*Grams*	*Calories*
Raisins	10	36
Beans, navy, dried	7	25
Peas, fresh	30	30
Tomatoes, canned	126	29
Rolled oats	13	52
Peanuts	25	139
Prunes	17	50

Lower Row, left to right	*Grams*	*Calories*
Onions	103	50
Lettuce	33	6
Bread, graham	20	52
Egg	17	25
Beef, lean	17	27
Potato	38	32
Cabbage	45	14
Spinach	14	3

a distinctly lower value for blood regeneration than liver. In nearly every case improvement was noted in a very short time, although some of the patients had been sufferers for years.

It is interesting to note that the baby comes into the world bearing in its body a special store of iron which serves as a reserve during the period of lactation. The percentage of iron in the infant's body at birth is about three times that of the adult's. During the first six months of life we make no effort to supplement the natural food, but in the latter half of the first year we begin to accustom the child gradually to egg yolk and suitable iron-bearing vegetables, so that as this reserve iron is used up in the rapid growth of the first year there may be fresh supplies to provide for further growth, as well as to make good the daily loss of this highly important element.

The iron in food, absorbed from the small intestine, is deposited mainly in the liver, bone marrow, and spleen where it is built into the complex iron-bearing proteins of the body (chiefly hemoglobin). When old worn-out red blood corpuscles are finally disintegrated, the iron is returned to the intestinal canal for elimination.

Such studies as have been made to determine iron requirement indicate that from 6 to 16 milligrams are required by an adult man to maintain equilibrium, and Sherman has concluded that a daily allowance of 15 milligrams is desirable.

The iron requirement of women is raised above the usual level by menstruation, pregnancy, and lactation. In view of the loss of blood in menstruation, it would

seem desirable to allow a woman at all times as much as the average man. Pregnancy and lactation make special drafts on the mother's iron supply, Sherman estimating that her iron requirement is increased by at least three milligrams per day. A suitable iron allowance for pregnancy and lactation would therefore seem to be one at least 20 per cent above the ordinary requirement. At the same time it should be borne in mind that the efficient use of iron depends on a number of other factors in the diet; that a liberal supply of calcium is favorable to good iron economy and hence the use of milk is desirable; and that iron is best utilized when secured in conjunction with egg yolk or liver, fruits and green vegetables.

The Requirement for Iodine

Our knowledge of quantitative requirements for mineral elements other than phosphorus, calcium, and iron is still meager. As these three are the ones most commonly deficient in American dietaries and as the foods which supply them contain a variety of other mineral elements, it does not appear to be likely that a diet adequate in these three will be inadequate in others, save in those regions where endemic goiter gives evidence of a low supply of iodine.

This element has already been referred to as essential to the thyroid gland, which serves as an important regulator of the basal energy metabolism and an indispensable factor in normal growth. Yet it was not until 1895 that conclusive evidence was brought forth that iodine was an essential element in thyroid structure and not until 1914 that thyroxin was prepared from

the gland by Dr. E. C. Kendall of the Mayo Clinic at Rochester, Minnesota, and shown to be an iodine-containing substance of marked physiological properties.

When he was able to remove iodine from thyroxin and show that the resulting product would not stimulate development, the place of iodine among mineral elements essential to the functioning of the human body could no longer be questioned, minute as the total amount in the body is—only about one-hundredth as much as of iron or less than the weight of one grain of wheat.

In the years from 1909 to 1913, Drs. David Marine and C. H. Lenhart, of Western Reserve University, were engaged in a study of goiter in brook trout in a hatchery where it had been prevalent for twenty-five years and where all the fish were goitrous. In the course of their investigations they found that fish fed exclusively with liver always developed the disease, while other fish of the same age and species in the same environment escaped when fed whole sea fish. They also found that trout with goiter had less iodine in their bodies than normal fish, and that adding minute traces of iodine to the water in which they lived prevented the disease or arrested it if already developed. Coming to the conclusion that the iodine in the sea fish was responsible for the benefits derived from feeding it, these investigators proceeded to demonstrate in several hatcheries the efficacy of iodine in preventing the disease, whether administered as food in the form of butterfish from the sea, or as tincture of iodine in a dosage of 1 part in 1,000,000 in the water of the hatchery.

Other animals suffer from iodine deficiency; it was estimated in 1916 that about one million young pigs

were lost annually in Wisconsin because of being born hairless and otherwise defective. In other western states (North and South Dakota, Washington, Minnesota) the pig industry was similarly menaced. The mothers appeared normal, but the thyroid glands of hairless offspring were found to be abnormally large and abnormally low in iodine. A careful canvass of the whole situation brought the conclusion that iodine starvation of the fetus depressed the activity of the fetal thyroid and caused the remarkable arrest of development. When suitable amounts of iodine were administered to the mothers during the gestation period there was not only prevention of the hairless condition but also a marked improvement in the vitality of the young pigs.

Other farm animals, such as horses, cattle, chickens, and dogs, have suffered extensively from goiter, and in all of these species administration of iodine has been as successful as with brook trout and pigs.

As old as history itself is the incidence of goiter in the human race. Kimball remarks that the *Arthorva Veda*, an ancient Hindu collection of incantations dating from 2000 B.C., contains extensive forms of exorcisms for goiter.[1] It was not until the middle of the nineteenth century, however, that the prevalence of goiter in European countries was made a matter of government investigation. For France alone, a commission appointed in 1864 reported ten years later 500,000 people suffering from goiter, and 120,000 cretins and cretinoid idiots. In all southern Europe the problem of goiter and

[1] Kimball, O. P. "Prevention of Simple Goiter in Man." *American Journal of Medical Sciences*, Vol. 163, page 634 (1922).

cretinism has been of sufficient economic importance to justify national commissions for its investigation.

In the United States there is a wide goiter belt stretching along the Appalachian Mountains as far north as Vermont, westward through the basin of the Great Lakes to the state of Washington, and southward over the Rocky Mountain and Pacific states; but no attempt to prevent human goiter on a large scale seems to have been made previous to 1917. Then Marine and Kimball, reasoning that if goiter could easily be prevented in brook trout, cattle, sheep, pigs, and poultry by administration of minute amounts of iodine, it should be preventable also in the human species, undertook to prove the possibility of such prevention in the public schools of Akron, Ohio, a large manufacturing town in the goiter belt. They secured the coöperation of the Superintendent of Schools, the Board of Education, and the County Medical Society, and in April, 1917, began a systematic census of the thyroid glands of all the girls from the fifth to the twelfth grades of the elementary school. The boys were not examined because of the relative infrequency of serious thyroid enlargement in boys. The results were as follows:

Incidence of Goiter in School Girls of Akron, Ohio, in 1917

State of Thyroid Gland	Number of Girls	Per Cent of Total Number Examined
Normal	1,688	43.6
Slightly enlarged	1,931	49.9
Moderately enlarged	246	6.3
Markedly enlarged	7	0.2
Toxic	39	1.0
Total number examined	3,872	

As many of these girls as volunteered were given small doses of sodium iodide dissolved in drinking water in quantity to furnish from 3 to 5 milligrams of iodine twice weekly over a period of a month, and repeated twice yearly. In 1920, as a result of two and one-half years' observations, the investigators reported that of over 2,000 pupils taking the treatment only five developed thyroid enlargement, while of a similar number not treated nearly five hundred showed enlargement during the same time.

Iodine and Goiter Prevention

This strikingly successful demonstration aroused much interest in goiter prevention both in other parts of this country and abroad. In the spring of 1918, Professor R. Klinger of Zurich, Switzerland, undertook to carry out similar treatment in three Swiss cantons, Saint Gallen, Berne, and Zurich, with school populations in which the incidence of goiter varied from 82 to 95 per cent. In 1922 a report of the Health Commission of the Canton of Saint Gallen gave the following statistics: incidence of goiter among all the school children of Saint Gallen, January, 1919, 87.6 per cent; January, 1922, 13.1 per cent.[1]

The prevention of goiter has thus been shown conclusively to be a nutritional problem. The body has a more or less definite requirement for iodine, to meet daily losses and maintain such a reserve as is necessary for the production of sufficient amounts of thyroxin for health and growth.

[1] Kimball, O. P. "Progress of the Work to Date on the Prevention of Simple Goiter," page 121. *Studies on the Prevention of Simple Goiter,* Western Reserve University Bulletin (1923).

How shall this iodine be secured? Study of goitrous regions has shown them to be remote from the sea and cut off from the supply of iodine in sea salt, which may be transported some distance inland as air-borne salt dust if not prevented by mountain ranges; or carried in water passing over salt beds. In regions so cut off, not only the drinking water but also the crops will yield little if any iodine, and the prevention of goiter is a problem for the health officer rather than the dietitian. What is needed is some safe method of iodine distribution which will reach the whole population. The three periods during which goiter develops being fetal life, adolescence, and pregnancy, not only the school population but the mothers in homes, no matter how isolated, must be reached. "In these endemic goiter districts, if every woman would keep her thyroid saturated with iodine during every pregnancy, she would not develop goiter, nor would there be any tendency to goiter in her child. This would save two of the goiter periods in the life of every individual. Then if every girl would keep her thyroid saturated with iodine during adolescence, that is, from the age of 11 to 16, inclusive, none would develop goiter.[1]

The effectiveness of administering to schoolgirls tablets containing iodine is experimentally demonstrated, but this way of solving the problem applies best to cities; and it does not reach expectant mothers. In several communities a wider distribution has been insured by adding iodide to the public water supply.

[1] Kimball, O. P. "Progress of the Work to date on the Prevention of Simple Goiter," page 122. *Studies on the Prevention of Simple Goiter*, Western Reserve University Bulletin (1923).

"As practiced at Rochester, New York, sodium iodide is added to the public water supply for a three-week period, twice a year. About seventeen pounds of sodium iodide are added daily, giving a concentration of 2/10,000 of a gram to a gallon, and the cost is in the neighborhood of $3,000 a year." [1]

This method is also applicable to cities rather than to rural districts. A third method is to add a trace of iodine to common salt. Crude salt contains iodine; it seems practical to restore a trace to refined table salt. One part sodium iodide to 5,000 parts salt is recommended. The main objection to this method is that here and there some one using salt excessively may get more iodine than is good for him.

These methods are all on trial and it is possible that others will be developed as we learn more about the iodine content of food and water and the iodine requirements of individuals. At present we have scarcely more than estimates of adult requirement; a man requires perhaps five milligrams of iodine per year, a quantity which would make a three-years' supply of iodine equivalent to the amount of iron needed for a single day.

Iodine in Food and Water

Our knowledge of the iodine content of food materials is as yet very limited, owing largely to the technical difficulties involved in determining such minute amounts of iodine as are found in common articles of diet. A curious instance of a single item of the diet preventing

[1] Report of the Committee on Nutritional Problems: "Iodine in Nutrition; Goiter as a Nutritional Problem." *American Journal of Public Health*, Vol. 14, page 1041 (1924).

goiter is found in Pemberton Valley in British Columbia. It is said that in former years every white baby born in this valley had a goiter, and nine-tenths of all the colts and the calves died. Yet in a village of Indians in this valley there was never any goiter, although Indians living in Minnesota, Michigan, and Wisconsin are as frequent victims as the white inhabitants. Keith, who has studied the Pemberton Valley, comments thus on the situation: "Whilst considering the lack of goiter among these Indians I would like to draw attention to the fact that they eat a great deal of salmon . . . and annually cure thousands for winter use. Their pigs also eat the dead salmon washed ashore on the gravel banks of the stream. It is quite probable that the Indians and their pigs get enough iodine from the salmon to give their thyroids the necessary quantum of this element."[1]

Jarvis, Clough, and Clark of the University of Washington have made a detailed study of canned and fresh salmon, which shows at the lowest over 100 parts of iodine per billion parts of moist substance and very frequently from 200 to 700 parts per billion, while such common fruits and vegetables as have been analyzed seldom yield as much as 25 parts per billion.[2] Other sea fish, such as cod, halibut, and haddock, are reported to yield about 250 parts per billion, while lobster, clams, oysters, and salmon roe give values running over 1,000 parts per billion.

[1] Keith, W. D. "Endemic Goiter." *Canadian Medical Association Journal*, Vol. 14, pages 284–289 (1924).

[2] Jarvis, N. D., Clough, R. W., and Clark, E. D. "Iodine Content of the Pacific Coast Salmon." *University of Washington Publications in Fisheries*, Vol. 1, No. 6, pages 109–140 (1926).

Von Fellenberg, employed by the Swiss Goiter Commission to study the distribution of iodine in nature, found that foods from a goitrous region contained less iodine than the same kinds from nongoitrous. He found milk (particularly milk fat), leafy vegetables, and fruits to be higher in iodine than other common types of food. Professor J. F. McClendon, of the University of Minnesota, has compared a number of foods from goitrous and nongoitrous regions in this country, with similar findings, the difference often being 100 per cent.

In a study of the incidence of goiter among Montana school children it was pointed out that enlarged thyroids were as a rule more prevalent in the isolated rural districts than in towns and cities where a greater proportion of imported green and canned vegetables was consumed. "Owing to a short summer season and altogether uncertain temperatures until as late as mid-June, few vegetables are grown in Montana for the local markets. Most of the vegetables used in Montana cities are shipped from southern California producers. Few of these vegetables, however, reach the isolated rural districts. In a number of the isolated rural schools of the Belt Mountain district of Cascade County, where the enrollments varied from 5 to 15 children, the writer found all children of both sexes to have enlarged thyroids. On inquiry made of a number of children in this district it was learned that a considerable portion of vegetables used at their homes throughout the year was home grown and home canned. The general rule in Cascade County was that the prevalence of thyroid enlargement among the children

of individual rural schools varied with the degree of isolation of the school district." [1]

From the earliest times it was popularly believed that the incidence of goiter was related to the water supply. Thus only did it seem possible to explain many instances of the close proximity of a goitrous to a nongoitrous region. Chemical evidence that this was not superstition or due entirely to other causes has lately been afforded by a study of goiter by the Department of Health of the State of Michigan. "It was found that localities separated only a few miles varied in percentage of thyroid enlargements in native children from 10 to 100 per cent. One notable instance of this where there are sufficient children for a satisfactory random sample was in the difference in percentage of thyroid enlargement between Mount Clemens, which had 26 per cent, and Romeo, 12 miles distant, which had 75 per cent. Mount Clemens has an iodine content in the city water supply of approximately 25 parts per billion, while Romeo water does not contain a trace of iodine in 50 liters." [2]

McClendon and Hathaway have made a study of the iodine content of water from various parts of the United States and find that much of the northern half of the country falls into a low-iodine division with less than 23 parts per billion, in contrast to the southern half, with more than 23 parts per billion; the goiter incidence in the north is from 5 to 30 per 1,000 men, in the south from 0 to 5. Yet it is not the simple drink-

[1] Foard, F. T. *Thyroid Enlargement Among Montana School Children.* Reprint No. 955, Public Health Reports (1924).

[2] Olin, R. M. "Iodine Deficiency and Prevalence of Simple Goiter in Michigan." *Journal of the American Medical Association*, Vol. 82, page 1331 (1924).

ing of water which prevents goiter; even in the case of waters containing 10 parts per billion of iodine, 10 quarts of water would have to be drunk to get 0.1 of a milligram of iodine, the dose recommended for a school child. The iodine in the water is to be regarded as indicative of the iodine in the soils which come in contact with the water. Plants growing in the soils are the agency by which it is concentrated for human use. In regions which are nongoitrous, it seems highly probable that most persons may secure sufficient iodine by a liberal inclusion of milk and green vegetables in their diet.

The Requirement for Sulphur

Sulphur is a component of body protein occurring, as we have already seen (page 138), chiefly in the form of the amino acid cystine. Sulphur is also an essential element in a recently discovered chemical regulator of metabolism called glutathione. This substance, found and named by Professor F. Gowland Hopkins of Cambridge University in 1921, is widely distributed in animal tissues and is regarded as an important factor in the control of the oxidative processes in the body.

Sulphur in food is found almost exclusively in the form of protein. Individual proteins differ considerably in their yield of sulphur, but the foods which ordinarily contribute most of the protein of the diet average about one gram of sulphur for each 100 grams of protein, or each 16 grams of nitrogen.

As the metabolism of sulphur usually runs somewhat parallel to that of nitrogen in the ratio of about one part of sulphur to 16 of nitrogen (corresponding to 100 grams of protein), we may assume for practical purposes that

the sulphur requirement will be met when the protein intake is sufficient to meet the nitrogen requirement.

Requirements for Other Ash Constituents

The amount of sodium chloride taken in the form of common salt is so far in excess of human requirements for sodium and chlorine as to overshadow the latter completely in everyday life. Furthermore, these elements are so widely distributed in food materials that there is little likelihood of shortage of either unless some specially restricted diet is employed over a long period of time. The main question is whether or not sodium chloride will be used to excess.

There is a relation between the amount of salt and the amount of water retained in the issues—the more salt the more water, and vice versa. In certain diseases affecting the circulation it is deemed desirable to restrict the amount of salt added to food in order to decrease the volume of fluid in the body.

Large amounts of salt also tend to stimulate the digestive tract and may thus interfere with the absorption of the food. For little children and invalids the use of foods preserved in salt is on this account objectionable. A good rule is probably to add always a little less salt than you would like.

"Potassium and magnesium are relatively abundant in meat (muscle) and also in most plant tissues, so that an ordinary mixed diet unless it consists too largely of refined food materials will usually furnish a safe surplus of these elements." [1]

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 287. The Macmillan Co. (1926).

Dr. Amy Daniels, of the Child Welfare Research Station, Iowa State University, reports that rats thrive better on milk when traces of fluorine, manganese, aluminium, and silicon are added to their diet, but nothing is known of the requirement of man for these elements. The idea of supplementing milk with these minerals came from the observation that the nutrition of rats on an exclusive milk diet was improved by adding soy beans, whose ash yields these elements. This illustrates how the addition of vegetables to the diet helps to insure a supply of the various minerals of which only very small quantities are needed.

Section 2

WATER

We have seen in Chapter VII that water is an indispensable constituent of body tissues and that even a substance seemingly dry, such as bone, owes more than one-third of its weight to water. Any considerable decrease in the normal amount of water in the body interferes with the manifold physical and chemical processes which are essential to life and health.

The serious conditions brought about by severe and protracted vomiting or diarrhea, or by fever, are partly due to dehydration. Infants with nutritional disorders may lose water from the body to such an extent that the flow of digestive secretions is reduced and the condition of the intestinal canal altered, with the result that food cannot be digested and absorbed, and feeding does no good until some means are found to restore the lost water to the tissues. Experimentally

it has been shown that a dog fed a water-free diet of dried meat and fat lost as much as 20 per cent of the water of his muscles in a few days and the food was regularly vomited because of the changes induced in the alimentary tract.

Certain insects can subsist upon food materials containing less than 10 per cent of water, i. e., as dry as a cracker, but these have a high energy metabolism and produce within their own bodies, through the combustion of their fuel foods, so-called metabolic water sufficient for their needs. Another interesting instance of meeting the body need for water by internal production is furnished by the camel, which, according to Babcock,[1] can go for long periods without drinking, more because of the fat of its hump and its carbohydrate food than because of the water in its stomach, the water formed in the process of food combustion being unusually well conserved by the coat of fine hair which reduces evaporation from the skin. Man, however, and most other large animals which excrete the nitrogenous products of their protein metabolism as urea, require a liberal supply of drinking water in addition to whatever they may acquire by metabolism or in food, to keep the urea content of blood and urine at a low concentration favorable to its excretion.

We must think of water in circulation as one of the conditions of health. Whatever its source, it is carried about and does its work without being chemically altered, again leaving the body as water, by way of kidneys, lungs, skin, and bowel. If we do not drink

[1] For an excellent discussion of metabolic water, see Babcock, S. M. *Metabolic Water.* Wisconsin Agricultural Experiment Station, Research Bulletin No. 22 (1912).

enough to make good the water loss the body soon ceases to function properly. Hawk states that in his laboratory normal young men put on a very low water ration soon gave evidence of abnormal function as shown by headaches, nervousness, loss of appetite, digestive disturbances and inability to concentrate on their work, symptoms which were promptly relieved by increased water intake. Hawk has made an extensive investigation of the effect of water upon the digestive process in normal individuals, and finds that water upon reaching the stomach immediately stimulates the gastric glands to greater activity and in other ways improves digestion, while the dilution of the contents of the intestine by a liberal water intake facilitates the absorption of the digested food. He concludes: "The average normal individual will find that the drinking of a reasonable volume of water with meals will promote the secretion and activity of the digestive juices, and the digestion and absorption of the ingested food, and will retard the growth of intestinal bacteria and lessen the extent of the putrefactive processes in the intestine." [1]

Circulation of water is also essential to the elimination of waste from the body, and the freer this circulation the more readily are injurious products removed. It is better to have dilute than concentrated urine, both for the sake of the urinary tract itself and for the organism as a whole.

Of purely regulatory functions attributable to water the most conspicuous is related to the control of body

[1] Hawk, P. B. "Water as a Dietary Constituent." Barker's *Endocrinology and Metabolism*, Vol. 3, page 294. D. Appleton and Co. (1922).

temperature. The pathway for heat loss varies with the temperature of the environment; at low temperature there is little evaporation of water, but when the temperature of the air approximates or exceeds body temperature water evaporation must remove all the excess heat. In the normal resting man, at a temperature of 23° C. (73.4° F.) and medium humidity, about one-fourth of the calories of the basal metabolism are dissipated through the evaporation of water as insensible perspiration and moisture from the lungs. This water, according to DuBois, amounts to about 700 grams (1½ lbs.) per day. Sweating promotes heat loss through evaporation if environmental conditions permit, and also favors conduction and radiation by increasing the moisture of the skin and perhaps of clothing. In a hot, dry atmosphere, the amount of water lost as perspiration is enormous. On the other hand, at a low temperature, sweating not only ceases but there is an actual mobilization of water from the blood into the tissues, so that less of it shall be brought to the surface to suffer cooling; thus the body heat is conserved.

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[1] Consult also the references for Chapter VII.

CHAPTER IX

FOOD AS REGULATING MATERIAL
THE VITAMINS

PART I

THE DISCOVERY OF THE VITAMINS

"All nutrition work, to be worthy of our present knowledge and opportunity, must stand four-square upon equal recognition of calories, protein, mineral elements, and vitamins." [1]

Having thus far given consideration to the first three, it now remains to see what rôle is played by the fourth group of substances essential to an adequate diet. Twenty years ago the word vitamin had not been coined, and the idea which it now connotes—minute quantities of substances which are to the human machine what the ignition spark is to the automobile—had scarcely been formulated. To Professor F. Gowland Hopkins, of Cambridge University, belongs the credit of first clearly stating the need of "accessory food factors" in nutrition: "No animal can live upon a mixture of pure protein, fat, and carbohydrate, and even when the necessary inorganic material is carefully supplied the animal still cannot flourish." [2]

[1] Sherman, H. C. "The Relation of Nutrition to Health," *The Red Cross Courier*, Vol. 4, page 7 (1925).

[2] Hopkins, F. Gowland. "Analyst and the Medical Man," *Analyst*, Vol. 31, page 385 (1906).

This was a new doctrine in 1906, when the ratio between the protein calories and the nonprotein calories was what was meant by a "balanced ration." At the University of Wisconsin, Professor S. M. Babcock determined to see whether or not rations balanced according to the approved standards of the time were equal in nutritive value, regardless of the source of the nutrients. With the coöperation at first of Hart and Humphrey and later of Steenbock and McCollum, an experiment was conducted on groups of young heifers, one group being fed a wheat-plant ration (wheat straw, wheat gluten, and entire wheat grain); another a corn-plant ration; a third an oat-plant ration; and a fourth a ration drawn from all three plant sources. All groups ate practically the same amounts of food and digested their rations equally well. For the first year of the experiment there was little to distinguish one group from another, but gradually the corn-fed group grew smoother in the coat and fuller in the barrel, while the wheat-fed group became rough of coat, gaunt and thin and small of girth. The groups on the oat-plant ration and the mixed ration stood intermediate between the corn-fed and the wheat-fed animals.

In addition to these outward signs there was a startling evidence of nutritive differences among the rations in the reproductive capacity of the animals. On the corn-plant ration the young were carried to full term, were able to stand and suck an hour after birth, and grew normally. On the wheat-plant ration the young were born prematurely, were small and weak and, if not stillborn, died within a few hours. The

young of the oat-fed mothers weighed nearly as much as those from the corn-fed mothers, but were all born prematurely and either dead or so weak that they died in a short time; only one, very feeble, was kept alive by very special care. The mixture of grains did not prove as satisfactory as the corn alone. McCollum says, in reviewing this work: "It was not possible by any means known to biological chemistry to work out a reason as to the cause of the pronounced differences in the physiological well-being of the different lots of cows." [1]

In other laboratories with other animals there were similar experiences. Hopkins in Cambridge, England, began about 1906 to feed young white rats a diet of casein, lard, starch, cane sugar, and mineral salts obtained by mixing equal parts of ash of oats and dog biscuit. When these substances were highly purified in the laboratory, growth was arrested and decline and death speedily ensued, even though the food intake appeared sufficient. When to the purified ration were added two or three cubic centimeters of cow's milk (3 or 4 per cent of the ration), growth was promptly resumed. This was very surprising because of the small amount of food added to the ration, and led Hopkins to say, "It is certain that there are many minor factors in all diets, of which the body takes account."

About the time that Hopkins was beginning this work, Osborne and Mendel in New Haven were initiating an investigation of the influence which proteins un-

[1] McCollum, E. V., and Simmonds, Nina. *Newer Knowledge of Nutrition*, 3d edition, page 15. The Macmillan Co. (1925).

like in their chemical make-up might have upon nutritive processes. They devised a ration in which all the dietary needs were met save that for protein, in order to add proteins from different sources and study their effects. These investigators, too, found difficulties in using highly purified fats, carbohydrates, and mineral salts, and ere long (1911) devised a preparation of milk freed of its casein, albumin, and fat, which they called "protein-free milk." By adding this to mixtures of pure starch, sugar, and fat along with any pure protein to be investigated, they were able to keep white rats alive through longer periods of time than had ever before been possible. At first they were inclined to think their success due to the ash of the protein-free milk, but very soon they discovered that this was not the case, as the use of an artificial protein-free milk was attended with failure. Hence the only possible conclusion was that some hitherto unsuspected substance must be present. They summed up the situation thus: "The animal cells need for their activities not only energy, but also suitable constructive material to replace the wear and tear therein. Furthermore the cells are concerned in the elaboration of a great diversity of complex and little understood substances such as enzymes, products of internal secretion, etc., which unquestionably play an indispensable rôle in life and may require either special antecedent products for their construction, chemical activators of some sort, or minute quantities of readily overlooked rarer elements and compounds. It is easy, yet futile at the present time, to develop detailed hypotheses respecting the almost innumerable possibilities involved. The greatest promise of success

in discovering the food factors which determine successful growth lies in seeking them in some chemical constituents of such diets as have proved adequate to promote growth." [1]

Section I

VITAMIN A

Although Osborne and Mendel were now able to make young rats grow for a time on a diet of casein, protein-free milk, starch, and lard, they found that beyond periods of about 100 days little or no increase in body weight could be induced, although the animals remained for some time in good condition.

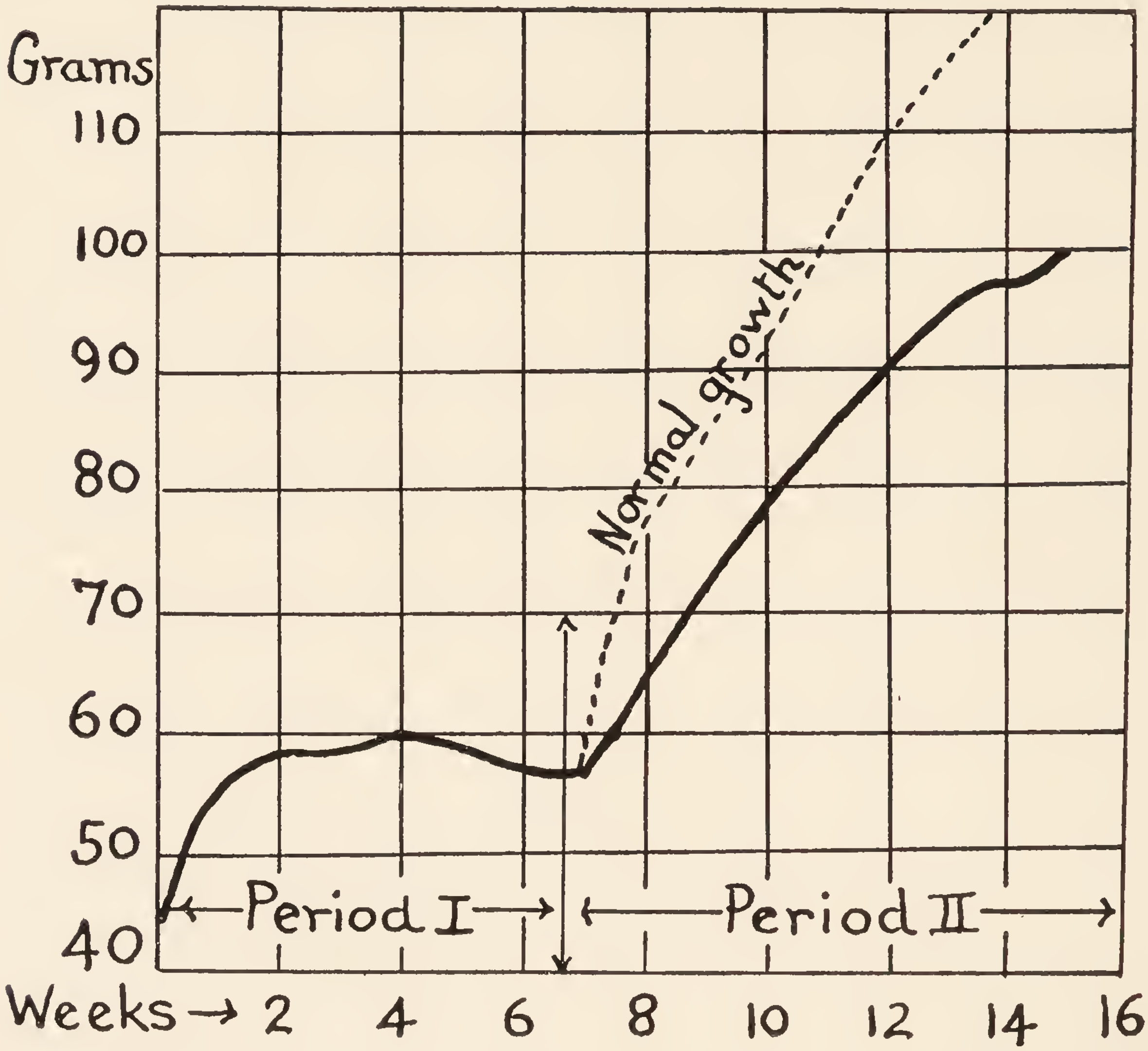
When whole-milk powder was substituted for the casein and protein-free milk they were able to bring young amimals through two generations. They concluded that the essential difference between the two diets lay in the milk fat. When, accordingly, butter was substituted for lard in the protein-free milk food, growth was promptly resumed and adult size attained. "It would seem, therefore," they said, "as if a substance exerting a marked influence upon growth were present in butter, and that this is largely, if not wholly, removed in the preparation of our natural protein-free milk." [2]

While these experiments were going on in the New Haven laboratories, progress in growth control was also being made in Wisconsin. McCollum and Davis,

[1] Osborne, T. B., and Mendel, L. B. "The Relation of Growth to the Chemical Constituents of the Diet." *Journal of Biological Chemistry*, Vol. 15, page 312 (1913).

[2] Op. cit., page 319.

meeting similar difficulties in promoting growth on rations of purified casein, carbohydrates, lard, and various salt mixtures, found that resumption of growth



(*After McCollum*)

FIG. 44.—This chart shows the speedy cessation of growth in a young rat when 3 per cent of cottonseed oil was the fat used in the ration (Period I) and the resumption of growth when a similar amount of olive oil which had been shaken with a solution of soaps prepared from butter fat was substituted (Period II). The olive oil had absorbed vitamin A from the soap solution.

occurred promptly when an ether extract of egg or butter was added. "We have seen this prompt resumption of growth after a period of suspension result from the introduction of ether extract of butter or of egg in about thirty animals and are convinced that

these extracts contain some organic complex without which the animals cannot make further increase in body weight, but may maintain themselves in a fairly good nutritive state for a prolonged period. In no instance have we obtained such a result by the feeding of lard, or of olive oil. It is therefore not merely the absence of fats from the diet which causes the suspension of growth." [1]

Thus two different laboratories, attacking the problem from quite different angles, simultaneously discovered that there is something in butter fat and egg yolk not found in lard and common vegetable fats which is essential for growth and which cannot be manufactured by the animal organism. This substance is now known as vitamin A.

Section 2

VITAMIN B

We must now turn our attention to another line along which knowledge of the vitamins has developed. For centuries there has been widespread in the Orient a nerve disease called beriberi, said to have been known to the Chinese as early as 2,600 B. C. The Malay States, Siam, Korea, Japan, and the Philippine Islands have been greatly afflicted by it, and it is more or less prevalent in India and in Africa. That it is not confined to tropical regions is shown by its occurrence in recent times in Newfoundland, Labrador, and Norway.

[1] McCollum, E. V., and Davis, Marguerite. "The Necessity of Certain Lipins in the Diet During Growth." *Journal of Biological Chemistry*, Vol. 15, page 175 (1913).

In 1872 there entered the Japanese navy a young medical officer named Takaki, who noticed the great havoc wrought by beriberi, and determined to find the cause and a remedy if it were possible. For the sake of more knowledge he went in 1875 to England and entered St. Thomas's Hospital Medical School, where he remained five years. Upon his return he was made Director of the Tokyo Naval Hospital, and began to study everything that might throw any light on the cause of this scourge. Referring to this period later, he said, "Such conditions used to strike my heart cold when I came to think of the future of our Empire, because if such a state of health went on without discovering the cause and treatment of beriberi, our navy would be of no use in time of need." [1] At this time there was an extra medical officer needed on every ship that made a long cruise because of the large amount of beriberi. On one ship 195 out of a total of 350 men were down with it at one time.

Takaki finally came to the conclusion that the disease was of dietary origin, and having been made Director-General of the Medical Department of the Navy, he succeeded in obtaining permission from the Japanese Admiralty to make a number of experiments in the service "upon a scale of great magnitude."

On December 19, 1882, the Riujo, a training ship bearing 276 men sailed from Yeddo Bay to New Zealand, South America and Hawaii, and then back to Japan, a voyage lasting 272 days. There were 169 cases of beriberi and 25 deaths before reaching Honolulu.

[1] Takaki, K. The Preservation of Health Amongst the Personnel of the Japanese Navy and Army. *Lancet*, 1906, I, page 1369.

Then Takaki sent the Tsukaba, another training ship with a similar crew over the same course, but with a better ration as shown by the following table:

	Diet on The Riujo	Diet on The Tsukaba
Food	*Weight ounces*	*Weight ounces*
Rice	27.78	32.16
Vegetables	9.56	12.41
Fish	4.85	6.56
Meat	2.18	8.02
Other food not specified	——	Milk and tea added
Total weight of ration	50.37	78.38

The Tsukaba was gone 287 days, but only 14 men had beriberi, and these did not eat their full allowance of the new ration. As a result of this experiment, in 1885 Takaki secured the adoption of a new dietary for the entire Japanese navy, in which the total food was further increased, the rice decreased, wheat and bread were added, the vegetables were increased and the milk allowance was made 1¼ pints daily. A year later (1886), in a force of 8475 men, there were only 3 cases of beriberi and no deaths. Not only was the dreaded disease eradicated by dietary measures, but the men were better nourished in every way, as is evidenced by the fact that from 1884 to 1893 the body weight of the men increased on the average 8 pounds. After that, from 1894 to 1903, it remained stationary.

A few years later, in the Dutch East Indies, Dr. C. Eijkman, director of the hygienic laboratory at Batavia, noted that certain fowls manifested symptoms curiously like beriberi, and began an investigation of the cause.

In 1897 he reported that the disease of the fowls (polyneuritis) was the same as beriberi in man, and was due to the lack of some substance essential to normal nutrition not present in polished rice but obtainable from the rice polishings. Eijkman induced the government to order an examination into the influence of rice feeding on human beriberi in the prisons of Java, by which it was shown that only one in 10,000 living on unpolished rice acquired the disease, while 3,900 in 10,000 living on polished rice developed it. The work of Eijkman was extended by Grijns, who showed that the antineuritic substance which Eijkman had found in the outer layers and embryo of the rice kernel also occurred in certain beans (*phaseolus radiatus*). Their efficacy was put to the test by the sanitary inspector of Java, who for nine months gave part of the inmates of a certain lunatic asylum white rice only and another group rice plus about 5 ounces of the beans daily, and found that no one who ate the beans had beriberi, while over one-third of those who did not eat them developed the disease.

Many other experiments with animals and human beings confirmed these findings of Eijkman and Grijns. One of special interest to Americans was the eradication of beriberi from the "Philippine Scouts" by Chamberlain of the United States army medical corps. Until 1910 the number of hospital cases had ranged from 115 to 618 annually in a force of about 5,000 men. In a single year, by the substitution of 16 ounces of unpolished rice and 1.6 ounces of dry beans for 20 ounces of polished rice in the ration, the cases dropped to 50, and in three years the disease had been completely wiped out.

Such experiences greatly stimulated effort to discover the nature of this antineuritic substance. Several independent investigators within less than a year (December, 1911—July, 1912) succeeded almost simultaneously in separating from rice bran and from yeast a substance which would cure the disease when induced in pigeons by feeding polished rice. Of these, Casimir Funk was the first to announce publicly that he had been able to cure, in a few hours, pigeons paralyzed by polyneuritis, by a few milligrams of the crystals which he had prepared from the rice bran (December, 1911). He suggested for this substance the name *beriberi vitamin.*

While Eijkman was investigating the antineuritic properties of rice polishings, Hopkins in England was seeking the reason why a very small portion of milk added to a diet of purified proteins, fats, carbohydrates, and mineral salts made the difference between nutritional success and disaster. He was able to show that in milk and certain vegetables there was something soluble in water and also in alcohol which, when added to the ration of purified foodstuffs, enabled young rats to grow.

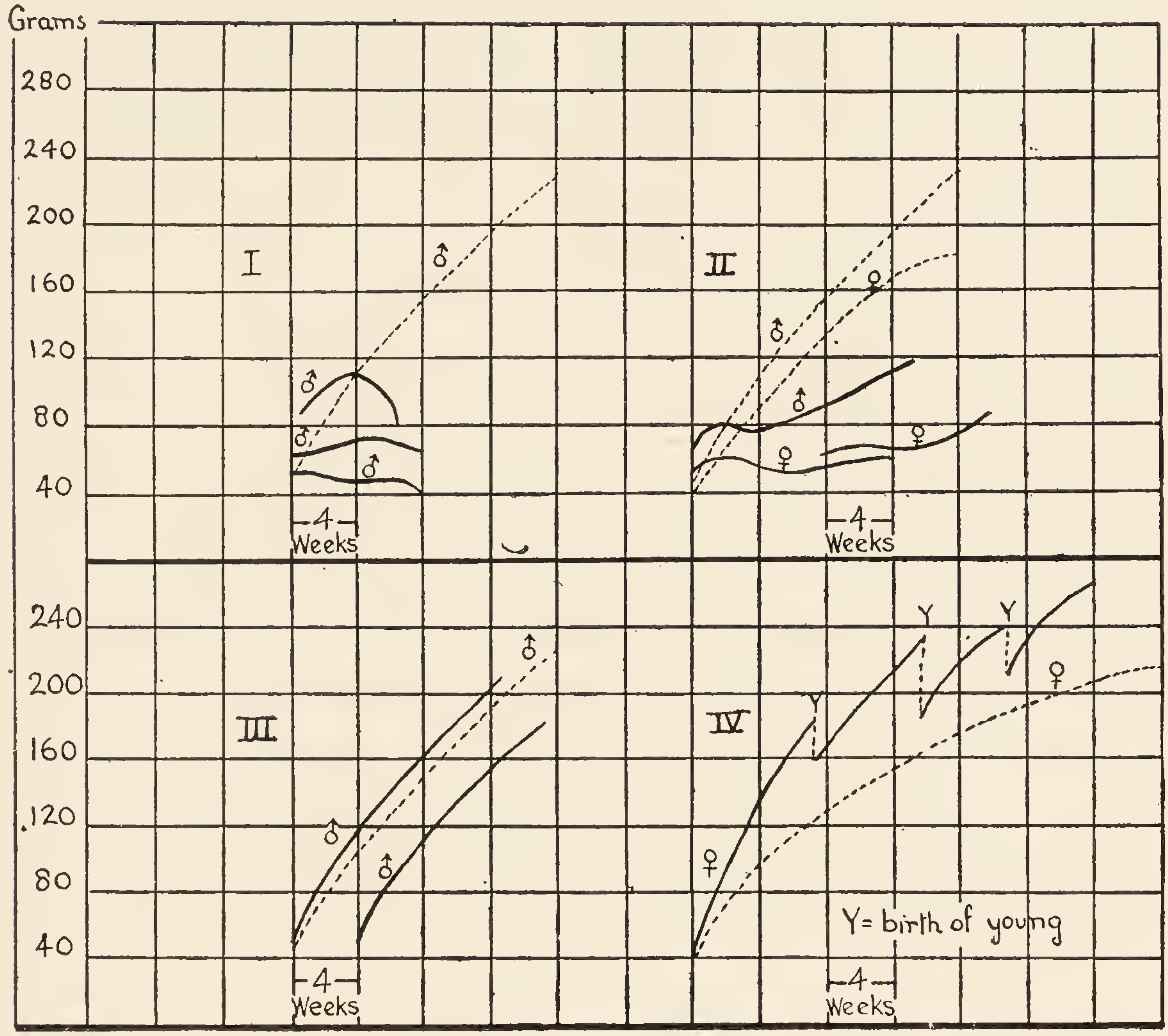
Also, in New Haven, Osborne and Mendel were finding repeated instances of the superiority of their "protein-free milk" over a mixture of pure lactose plus pure mineral salts from the laboratory bottles, which led them to realize that they were dealing with some specific water-soluble growth-promoting substance.

This was also just about the time that Hart, Humphrey, Steenbock, and McCollum published the first

report of their investigations in feeding cattle on rations from a single plant source, which started them on a long series of experiments to find out why there had been such good results with the corn plant and such poor ones with the wheat plant. They turned their attention first to the wheat kernel, and McCollum and Davis found that it was necessary to supplement the grain by the addition of casein, a mixture of mineral salts (to make the ash content of the diet much like that of milk), and butter fat. When this was done the diet proved satisfactory for the growth of the young to maturity, the maintenance of the adult, and the production of vigorous offspring.

They next turned their attention to polished rice and tried the same procedure which had revealed the nature of the dietary deficiencies of wheat. They were surprised to find, however, that polished rice supplemented with casein, butter fat, and a suitable salt mixture not only failed to induce growth in young rats, but did not fully protect them from polyneuritis. They had previously secured growth on a mixture similar in all respects to the supplemented rice ration save that starch was partly replaced by milk sugar. So they tried milk sugar in the rice diet, and found that when it constituted 5 per cent of the ration they got some growth; when it was raised to 10 per cent, much better growth; if, however, the milk sugar were highly purified in the laboratory, the diet would no longer induce growth. They then took the water from which the milk sugar had crystallized out and evaporated this on the food mixture, with the result that the ration so reinforced was now able to sustain growth. McCollum

had already suggested the term "fat-soluble A" for the growth-promoting substance found in egg and



(*After McCollum*)

FIG. 45.—The dotted lines indicate the normal rate of growth of the male (♂) and the female (♀).

Lot I, fed polished rice, a complete salt mixture and butter fat for vitamin A, was unable to grow because of lack of vitamin B.

Lot II, fed a diet improved by the addition of casein to the polished rice, salts and butter fat, could grow very little because vitamin B was still lacking.

Lot III, fed a diet like Lot II except that unpolished rice was substituted for polished, grew well because the bran and germ furnished vitamin B.

Lot IV, fed a diet of polished rice, salts, casein and butter fat to which was added the alcoholic extract of wheat embryo, also grew well because the extract of the wheat germ furnished vitamin B.

butter fat; it was natural, therefore, to designate this new substance by the corresponding term "water-soluble B," described as "a second dietary essential,

of which an animal needs but a very small amount, but which is absolutely necessary for growth in the young and for maintenance of health in the adult."[1] In this way, in 1915, they furnished concrete evidence of the soundness of the view expressed by Mendel in 1914, that there are at least two "determinants" in the nutrition of growth: one in protein-free milk, the other in butter fat or cod-liver oil or egg yolk.

McCollum found that pigeons could be cured of polyneuritis by adding to polished rice the same preparation of "water-soluble B" which had been found to induce growth in rats, and Funk made a preparation from yeast which was both antineuritic and growth-promoting. Once more two very different lines of investigation came together; polished rice proved inadequate for rats as well as for pigeons, and other foods yielded extracts possessing the antineuritic and growth-promoting properties which are now ascribed to vitamin B.

Section 3

VITAMIN C

It is again necessary to turn back the hands of time many centuries, to the period when scurvy was a constant menace to sailors, soldiers, and explorers, and at intervals swept over great areas of land, especially in northern regions where people had to subsist for a large part of the year on a diet consisting mainly of grain products and meat or fish. The French crusaders are reported to have suffered greatly from it in the

[1] McCollum, E. V., and Simmonds, Nina. *Newer Knowledge of Nutrition*, 3d edition, page 36. The Macmillan Co. (1925).

thirteenth century. On Jacques Cartier's second voyage to Newfoundland in 1535 "he wintered near an Indian village, Stavacona, in Quebec. Both the Indians and his crew were afflicted with scurvy. Between December and the middle of March, 25 men from his crew died, and the rest were so sick that recovery was despaired of except for three or four. The middle of March, Cartier noticed an Indian whole and sound who had been very ill with scurvy ten or twelve days earlier. He asked the Indian how he had healed himself and was told that he had taken the juice and sap of the leaves of a certain tree called 'Ameda.' At Cartier's request, the Indian had branches brought and showed how the bark and leaves should be boiled together and the resulting decoction taken every other day. So successful was the remedy that all Cartier's crew were speedily completely cured, and the narrator goes on to say: 'It wrought so well, that if all the physicians of Montpelier and Louaine had been there, with all the drugs of Alexandria, they would not have done as much in one yere as that tree did in sixe days, for it did so preuaile, that as many as used it, by the grace of God recouered their health.' He explains that the 'Ameda' is thought to be the sassafras tree, but this incident occurred the middle of March at a season when 'our captaine' was walking from his boat to the shore upon the ice at the time he saw the Indian who had been healed, so the 'Ameda' could not have been a deciduous tree. Lind believed it to be the American spruce." [1]

[1] Appleton, V. B. "Spruce Beer as an Antiscorbutic." *Journal of Home Economics*, Vol. 13, page 604 (1921).

In 1747, this same Dr. Lind, who was a surgeon in the British navy, conducted a most interesting experiment to compare various articles of diet as to their antiscorbutic properties, using as subjects twelve sailors sick with scurvy on board the "Salisbury," at sea. They had one diet common to all, water gruel sweetened with sugar in the morning, fresh mutton broth oftentimes for dinner; at other times light puddings, boiled biscuit with sugar, etc.; and for supper, barley and raisins, rice and currants, sago and wine, or the like. The men were divided into pairs. One pair had each a quart of cider daily; another, a spoonful of vinegar three times a day. Two of the worst had half a pint of sea water every day; two others had each two oranges and one lemon; two others had a most amazing compound of seeds, gums, etc., with a drink of barley water acidulated with tamarinds. The result of this nutrition experiment was that in six days "the most sudden and visible good effects were perceived from the use of the oranges and lemons." He recommended that thereafter lemon juice evaporated to a syrup should be carried in all ships for the safeguarding of the sailors, and in 1795 regular administration of lemon (called lime) juice was prescribed in the British navy, wherefore British sailors are to-day familiarly known as "limies."

With the introduction of the potato into northern Europe scurvy greatly decreased on land, extensive outbreaks occurring only when crops failed or other misfortune deprived the people of their usual food. In 1915 and 1916, in Mesopotamia, during the siege of Kut-el-Amara, there were 1,050 cases of scurvy,

practically all confined to the Indian troops. The British soldiers escaped partly because they were in a better nutritional state to begin with and partly because they were eating fresh meat, which, although a poor antiscorbutic, did help to postpone the onset of the disease. In the last period of the siege, in spite of a very inadequate amount of food and rapid loss of weight, the use of about three ounces per capita per day of green herbs gathered from the plains caused the scurvy to abate. The inability of men to subsist long without some food which would guard them against scurvy received fresh demonstration during the World War.

Systematic Study of Antiscorbutic Foods

At the close of the nineteenth century it was known from practical experience that certain foods would cure scurvy and various theories had been proposed to account for the antiscorbutic power of these foods, none of which had proven tenable. Then in 1907 two Norwegian investigators, Holst and Frölich of the University of Christiania, stimulated by the success of Eijkman and others in producing experimental polyneuritis in pigeons by a faulty diet, undertook similar experiments in the hope of finding the cause of ship beriberi. This had become suddenly prevalent among Norwegian sailors, Holst states, because about 1894 in response to public demand shipmasters were compelled to supply sailors with bread made from white wheat flour in place of rye flour milled without removal of the germ, as had been customary up to that time.

Instead of pigeons Holst and Frölich used guinea pigs and found to their surprise that when fed polished rice

these developed, not beriberi, but *scurvy*. Further investigation showed that a diet of oats or any other grain or bread resulted in a scorbutic condition, but the feeding of grain plus a moderate amount of cabbage, dandelion, carrot, potato, or other fresh vegetable prevented the disease. Most significant was their finding that certain foods such as cabbage, carrots, and cauliflower lost their antiscorbutic property on heating or drying, while some others, such as potatoes and turnips and fruit juices, remained antiscorbutic after cooking.

Fürst, working in the same laboratory, experimented with peas, lentils, and almonds, and found that they resembled cereals in their lack of the antiscorbutic substance, but that when soaked and allowed to sprout they developed antiscorbutic properties. He also tried various combinations of seeds, and wisely concluded that "there is no advantage in numerous foods when none contains the needed substance."[1]

The work of Holst and Frölich was rapidly extended after 1913 by other investigators. Dr. Alfred F. Hess, of New York City, in 1914 described outbreaks of scurvy in an infant orphan asylum where the children had been fed pasteurized milk, without any orange juice or other antiscorbutic, and showed that small amounts of orange juice or a little mashed potato were more effective as a cure than the substitution of raw for pasteurized milk.

In 1916 Dr. Harriet Hume and her associates of the Lister Institute in London began a long series of studies

[1] Cited by Sherman, H. C., and Smith, S. L. *The Vitamins*, page 97. The Chemical Catalog Co., Inc. (1922).

of the antiscorbutic properties of foods and the results were most useful during the World War in feeding the armies in the field and the civilians at home. The use of sprouted peas and beans was recommended for the army ration when other antiscorbutic food was scarce, and yellow turnip juice was recommended for the protection of young children in London.

An old superstition against the tomato as a food for children was set aside by Hess, who demonstrated that canned tomato juice could be used as an antiscorbutic in place of orange juice, even for babies one month old.

That the acid of citrus fruits was not the antiscorbutic substance was proven by Hess, who showed the white inner part of orange peel to be antiscorbutic as well as the juice; and who was able in 1918 to extract the antiscorbutic substance from orange juice by means of alcohol.

Notwithstanding the rapidly accumulating evidence that Holst and Frölich were right when they concluded in 1912 that scurvy was due to the absence of a certain chemical substance from scorbutic diets, one curious fact sustained those who were skeptical as to the existence of an antiscorbutic vitamin. This was that rats, which require vitamins A and B, do not have scurvy. For a time it was thought quite generally that they could attain perfect nutrition on a scorbutic diet, but in 1919 Professor J. C. Drummond of the University of London reported a feeding experiment in which rats were kept for two generations on such a diet, and stated his findings in the following words: "The rat requires the antiscorbutic factor in order to achieve a normal development, and al-

though the requirements of this species are of a very much smaller order than those exhibited by man, the monkey, or the guinea pig, they are sufficiently well marked to dispel any idea that there exists a fundamental difference in the nutritive requirements of the two types of animals." [1]

A little later Dr. Helen T. Parsons, of the Johns Hopkins University, explained the power of the rat to endure deprivation of antiscorbutic food by showing that rats had an antiscorbutic substance in their bodies. She fed to scorbutic guinea pigs the livers of rats which had subsisted for a long time on a scorbutic diet. The symptoms of scurvy disappeared and the animals gained rapidly in weight, thus giving evidence of having received the lacking factor in their diet from the rat livers.

The fact that rats thrive as well as they do on diets containing but little antiscorbutic substance seems to indicate that their needs in this direction are relatively small. At any rate, it has been clearly established that the rat cannot absolutely dispense with vitamin C any more than other higher animals.

The evidence was now clear and convincing that in addition to protein, fat, carbohydrate, mineral salts, and vitamins A and B, an adequate diet must also contain an antiscorbutic substance for which Drummond suggested the name vitamin C.

[1] Drummond, J. C. "Note on the Rôle of the Antiscorbutic Factor in Nutrition." *Biochemical Journal*, Vol. 13, page 77 (1919).

SECTION 4

VITAMIN D

Following the discovery of vitamins A and B, investigations of the nutritive properties of food materials went forward by leaps and bounds, accompanied by a growing appreciation of the rôle of such foods as milk and green vegetables in the diet and a desire to know more specifically how these differ in nutritive value. Also renewed interest in the so-called deficiency diseases was manifested. It was observed that as soon as vitamin A was withheld for a considerable time from experimental rations, whether fed to rats or dogs, the animals frequently became the victims of sore eyes, and this focused attention on another disease, xerophthalmia, which will be discussed in more detail a little further on.

Studies of growth on controlled rations were made with increasing discrimination, standards of normal growth for the white rat having been formulated by Dr. H. H. Donaldson, Director of the Wistar Institute in Philadelphia. While at first research workers had been delighted to keep adult animals alive and well for 300 or 400 days or young ones growing from 60 to 100 days, they now knew that unless their animals grew at the normal rate through the whole period of development, reproduced at the proper time, bore offspring as vigorous as themselves, and passed away only in a ripe old age, their rations were in some respect inadequate. The spirit of the times is well expressed by McCollum: "Once a pathologic condition is produced experimentally in an animal, either by accident

or design, if it be due to defects in the dietary, the solution of the problem and the correction of the dietary fault can be undertaken with the certainty that success will be the reward of effort. This follows from the completeness of our present-day knowledge of the essentials of a complete diet and of the great body of dietary information which we possess concerning the quality of many natural foodstuffs with respect to each of the essential nutrient principles. Experimental diets can now be planned which have any defect or defects desired, and which are known with reasonable certainty to be complete in all other respects." [1]

Rickets In Children

For many years there had been a belief that a faulty diet bore some relationship to the disease known as rickets. This is the most common disease occurring among children in the temperate zones. It was first described by an English physician, Francis Glisson, at the beginning of the seventeenth century and it is still widely prevalent; the British Medical Research Council of Great Britain in 1924 refers to it as "a long-standing curse." It occurs more frequently among the poor than the well-to-do, and in cities than in rural districts; it is estimated that fully three-fourths of the infants in our great cities manifest rachitic signs in some degree.

Although rickets is a disease of many symptoms, affecting the whole body, its most characteristic symptom is a failure of the bones to calcify properly, with

[1] McCollum, E. V. "Our Present Knowledge of the Vitamins." *Lectures on Nutrition of the Mayo Foundation*, page 180 (1925).

resulting deformities. The first to appear is the so-called "rachitic rosary"—a row of bead-like protuberances down each side of the chest where the bones of the ribs join the costal cartilages.[1] The chest fails to develop properly and the lung space is contracted, interfering with deep full respiration. The ends of the long bones become enlarged, especially at wrists and ankles. Calcium salts are not deposited in the normal way. The evidence is seen at the point of junction of the shaft of the bone with its head, called the epiphysis. In the normal bone this junction is a straight, clear line; in the rachitic bone it is ragged if not wholly obscure. The cartilage of the epiphysis is not converted into bone, but persists and increases, and there is an irregular enlargement of soft tissue. The difference between normal and rachitic bone is shown in Fig. 46.

Curvatures of all sorts occur in the poorly calcified bones and the bones of the skull develop "bosses" on the sides and front, so that the shape becomes square. The development of the pelvis is also arrested and this in females is likely to make the bearing of young more perilous. Reporting an intensive study of rickets made by the New York Association for Improving the Condition of the Poor in lower New York, Gebhart says: "We also found that while deformities of the extremities such as 'bowed legs' or 'knock knees' tend to disappear, those of the thorax and pelvis are retained for many years, if indeed they are ever fully outgrown. The flattened and narrow rachitic pelvis of girls, if not 'outgrown' causes complications and

[1] This beading may be seen distinctly in Fig. 38, page 169.

(*Courtesy of Dr. D. B. Phemister*)

A B

Fig. 46.—A case of severe rickets before (A) and after (B) treatment. "A" shows the tibia and fibula of a child 2 years 10 months old with long-standing rickets. There is marked curvature and the shadows of the shafts are expanded and faint. The centers of ossification of the epiphyses cast faint shadows with irregular outlines. There are also marked porosity of the shafts.

"B" shows the same bones after 106 days of treatment. There is a very striking change. The shafts are much denser and their ends show a dense, narrow line along the zone of ossification. Of all the rachitic signs only the curvature persists.

involves considerable risk of life for both mother and baby during childbirth.

"Children who suffer from rickets usually show a protuberant abdomen which is the result of low muscle tone. The weakness of the muscles together with the narrow chest, so characteristic of the disease, results in diminished breathing capacity which renders the ricketic child susceptible to respiratory troubles, bronchitis, pneumonia and even tuberculosis. Mulberry district seems to bear this out—respiratory complaints are the leading causes of death in children under five."

Experimental Rickets

Among the confusing observations in regard to the etiology of rickets one of the most puzzling was that the apparently well-fed child often fell a victim to the disease and that cutting down the amount of his food might bring about improvement. In 1908, Dr. Leonard Findlay, at the University of Glasgow, produced rickets in a group of puppies in laboratory cages on a milk and porridge diet. Inasmuch as another group allowed to run in the open did not contract rickets, he thought that muscular exercise was the explanation of the difference. In 1917, McCollum and Simmonds, studying the dietary deficiencies of the cereal grains, observed that many rats developed beaded ribs and other skeletal deformities and they tried all sorts of changes in the mineral content of their rations to prevent these abnormalities of the skeleton which so strongly suggested rickets. They were convinced that the cause lay in the diet. They said that the diet was the sole

determining factor in the etiology of the lesions in question, for the entire colony of approximately 2,000 animals lived under identical conditions except for those related to the composition and source of their food.[1]

While these observations were being made in Baltimore, Dr. E. Mellanby in a research conducted for the Medical Research Council of Great Britain succeeded in inducing rickets in puppies by means of various faulty diets, such as bread or other cereal food with a little whole milk; or bread and a little separator milk, with linseed oil to replace the milk fat. When cod-liver oil was substituted for other fat in the rachitic diet, the disease was prevented; since cod-liver oil was by that time (1919) known to be rich in vitamin A, Mellanby concluded that this vitamin must be antirachitic as well as growth-promoting.

Inasmuch as rickets is a disease in which the bones are deficient in calcium, the very natural notion was widespread that administration of calcium should cure it. However, dosage with calcium generally gave disappointing results and rickets sometimes developed when children were fed liberally on cow's milk, rich in calcium. In 1921, Sherman and Pappenheimer threw light on this anomalous situation from another angle. They reported that rickets could be speedily induced in rats by the use of a diet lacking fat-soluble vitamin, high in calcium, and low in phosphorus; and that this rickets-producing diet could be changed to an anti-

[1] McCollum, E. V., Simmonds, Nina, Parsons, H. T., Shipley, P. G., and Park, E. A. "Studies on Experimental Rickets. I. The Production of Rachitic and Similar Diseases in the Rat by Deficient Diets." *Journal of Biological Chemistry*, Vol. 45, page 333 (1920).

rachitic one by the simple addition of a suitable amount of a phosphorus salt.

A little later the Johns Hopkins investigators, having also succeeded in evolving a rickets-producing diet low in phosphorus, made the further observation that butter fat, while preventing the disease which results from shortage of vitamin A, did not satisfactorily modify the pathological condition of the skeleton; "if anything, it was intensified, probably as a result of the slight stimulation given by the butter-fat to the growth of the bone." [1]

On the other hand, when cod-liver oil was added to the diet there were no signs of rickets. Within the year (1921) this difference between butter fat and cod-liver oil was explained. Hopkins had pointed out in 1920 that if oxygen was allowed to pass through a heated fat any vitamin A which it contained would be destroyed, and very shortly McCollum in Baltimore, Steenbock in Madison, and Coward and Drummond in London reported that cod-liver oil so treated lost its growth-promoting power but retained its antirachitic property.

It was found, too, that the antirachitic substance could be separated from the fat of cod-liver oil. Dr. T. F. Zucker, of the College of Physicians and Surgeons of Columbia University, in 1921 devised a method of making a preparation many times more powerful than the original cod-liver oil, and entirely free from vitamin A. This removed the last doubt that the antirachitic

[1] Shipley, P. G., Park, E. A., McCollum, E. V., and Simmonds, Nina. "Studies on Experimental Rickets. V. The Production of Rickets by Means of a Diet Faulty in only two Respects." *Proceedings of the Society for Experimental Biology and Medicine*, Vol. 18, page 278 (1921).

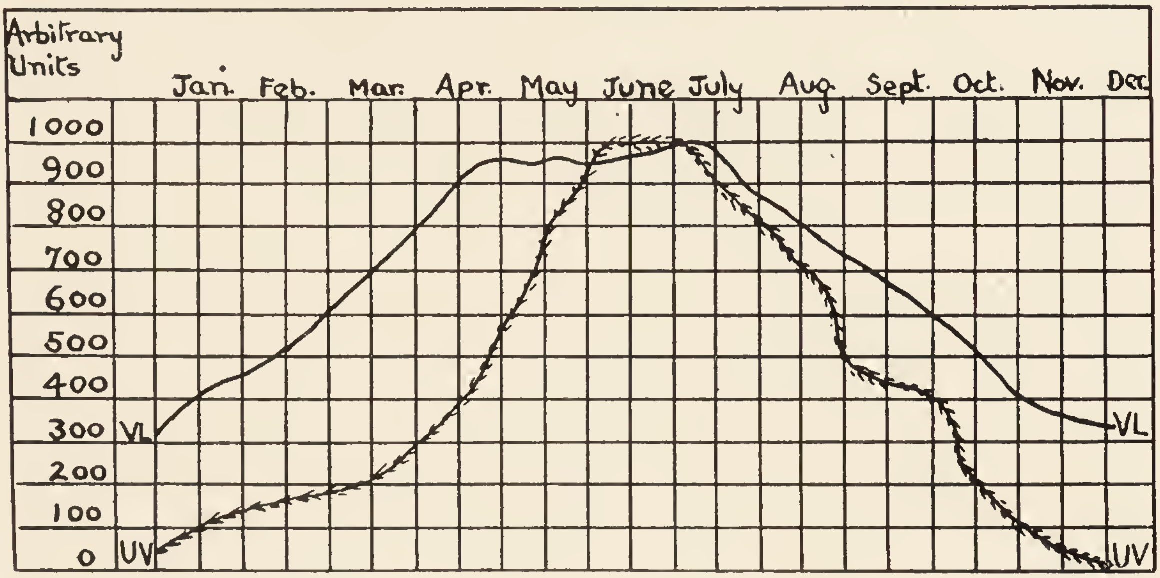
substance was a definite chemical entity, entirely distinct from vitamin A, but since it then seemed to be limited to fish-liver oils, instead of being found in a variety of common food materials like the other vitamins, there was still doubt as to whether it should be put in the same category.

Interest in rickets was now very keen and new means of clinical and laboratory study opened up a wide field for investigation, while knowledge of the curative power of cod-liver oil gave hopes of eventually eradicating rickets from the earth. In 1920, Drs. John Howland and Edwards A. Park, of the Department of Pediatrics of the Johns Hopkins University, reported at the annual meeting of the American Pediatric Society that they had been able, by means of the Röntgen ray, to observe the actual deposition of calcium in the bones of rachitic infants under the influence of cod-liver oil therapy, and the next summer Howland and Kramer showed that another delicate sign was the regular reduction of the inorganic phosphorus of the blood serum of infants with active rickets.

Rickets and Sunlight

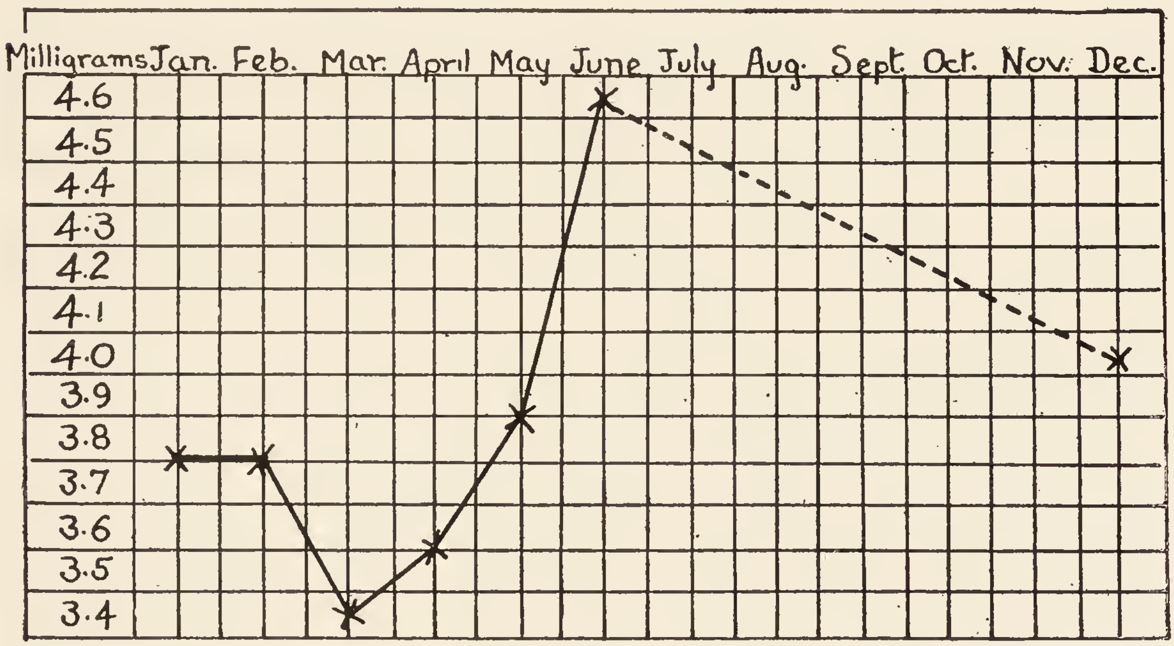
Studies with the newer technics did not proceed far ere it was discovered that there was a marked seasonal variation in rickets, the disease being more prevalent in winter than in summer. In 1921 it was demonstrated by Hess in New York and by Shipley, Park, Powers and McCollum in Baltimore that the development of rickets in rats fed a standard rickets-producing diet could be prevented by daily exposure to direct sunlight, and proof was given for the first time

by Hess and Unger that the low inorganic phosphate of the blood serum of rachitic infants could be raised



(*After Hess*)

Fig. 47A.—Seasonal Variation in Visible Sunlight (VL) and in Ultra-violet Light (UV).



(*After Hess*)

Fig. 47B.—Seasonal Variation in Blood Phosphate.

Note the correspondence between the peak of blood phosphate and the maximum of sunlight and ultra-violet light.

to the normal level by daily sun baths. Thus was confirmed the strong belief of many that hygiene played a significant rôle in rickets, and thus, too, was

explained the irregularity with which rickets occurred in the same community.

It did not take long to discover a correlation between the seasonal tide of blood phosphate and the amount of sunshine at different times of the year; and it was but one step more to the application of "artificial sunlight" by means of a carbon arc lamp similar to that employed in taking motion pictures, and to realization of the fact that it is the ultra-violet rays of the sun which possess the curative properties. This resulted in the use of the mercury vapor quartz lamp, which emits a larger proportion of these rays and which had already been employed with success in the treatment of rickets in Germany. In every instance there was a rapid decline in the signs of rickets, attested both by Röntgen ray examination of the bones and by the regular increase in the blood phosphate. At this time Powers, Park and others of the Johns Hopkins University group wrote: "It would seem that diets which suffice for the maintenance of optimal health during a life in darkness may supply an amount of dietary factors unnecessary for an individual who is irradiated by sunlight. From this point of view it becomes necessary to think of certain factors which can be taken into the body in the food as being able to compensate for deprivation of light, and of light as being able to compensate for the deprivation of certain dietary factors. The experiments suggest, therefore, that throughout the animal and perhaps also the vegetable kingdom there may be balances between the amounts of active light required and the amounts of certain food essentials requisite for the maintenance of health.

Under the abnormal conditions imposed on animals by domestication or on man by civilization, it may be necessary to supply more light to replace the lack of certain dietary essentials or to increase the latter to compensate for deprivation of light." [1]

Sunlight and Vitamin D

The solution of the mystery as to how the same effect could be secured by such diverse agencies as cod-liver oil, direct sunlight, ultra-violet light or a ration carefully balanced with regard to calcium and phosphorus was not forthcoming until two years later (1924), when Steenbock and Black, pondering on the observation of two English biochemists (Goldblatt and Soames) that rat livers irradiated with ultra-violet light were able to promote growth when fed to other rats, were impelled to repeat these experiments and also to try feeding an irradiated ration to rats on a diet devoid of any antirachitic substance. Doing so, they found that the irradiated rat rations became possessed of antirachitic properties and that not only liver, but also lung and muscle tissue from irradiated rats, promoted bone calcification, while that from nonirradiated rats was not antirachitic. While this paper was in the hands of the publishers, Hess reported to the American Pediatric Society that he had been able to confer the antirachitic property upon two otherwise inert oils, cottonseed and linseed, as proven by their curative effect upon rachitic rats, but that negative results followed irradiation of liquid petrolatum.

[1] Powers, G. F., Park, E. A., Shipley, P. G., McCollum, E. V., and Simmonds, Nina. "The Prevention of the Development of Rickets in Rats by Sunlight." *Journal of the American Medical Association*, Vol. 78, page 164 (1922).

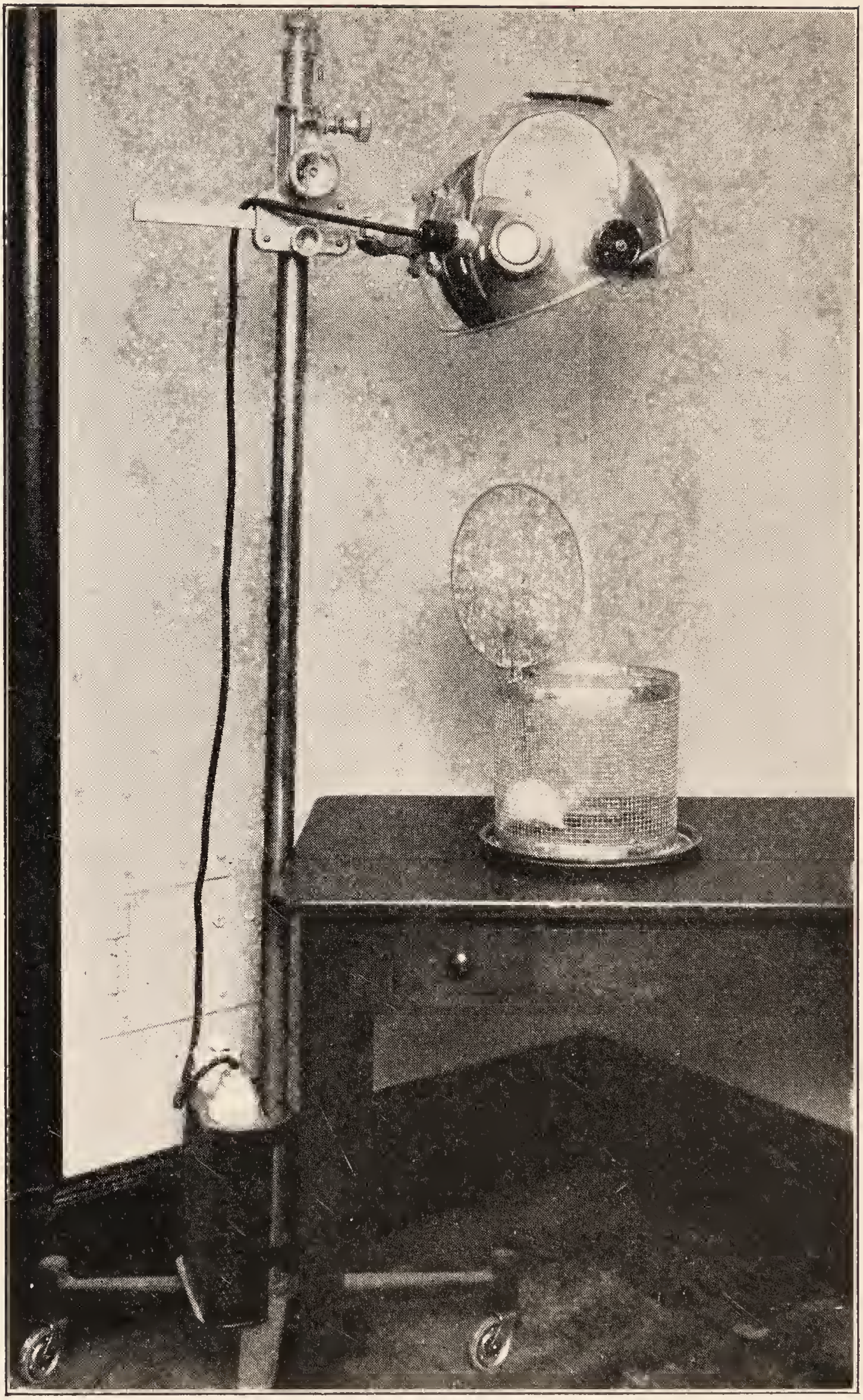


FIG. 48.—A Mercury Vapor Quartz Lamp which Emits a Light Richer in Ultra-violet Rays than Sunlight.

These two investigations appeared in print in the same month (August, 1924), and left but one link in the chain of researches which should finally trace the connection between light and diet. As fast as possible, all sorts of materials were irradiated and tested. Consideration of the kind of material which could be successfully treated together with studies of the chemical nature of the antirachitic concentrate prepared from cod, burbot, shark, and other fish-liver oils, led to the belief that the substance acquiring this property was cholesterol (or a substance very closely related chemically known as phytosterol). Again almost simultaneously Hess and Weinstock (May, 1925) and Steenbock and Black (June, 1925) published evidence that cholesterol (or phytosterol) present in cod-liver oil, egg yolk, and other naturally antirachitic substances, is the substance which responds to irradiation. That the action of light on the body is of the same nature was also shown by Hess and Weinstock, who, recognizing that ultra-violet radiations do not penetrate the skin, undertook to find out whether this tissue could be activated after it had been removed from the body. Skin is richer in cholesterol than any other part of the body except the brain, and when irradiated proved fully protective against rickets.

Cholesterol is widely distributed in the animal body and phytosterol in plant tissues and the capacity of any substance for becoming antirachitic upon irradiation with ultra-violet light is now believed to depend upon the presence of one of these substances. Pure proteins, carbohydrates, salt or water cannot be activated. For years the reason for the occurrence of

cholesterol in the body has been a puzzle to physiologists, but now we may regard the skin as an organ reactive to particular light waves and irradiated cholesterol as the vitamin which acts as a regulatory mechanism to adjust any lack of balance between calcium and phosphorus in the blood, bringing about such a relationship as makes possible the deposition of calcium phosphate in the skeletal tissues. The linking up of light with food factors in nutrition is a triumph of biochemical research of the greatest significance for human welfare. Vitamin D takes a rightful place among the significant regulatory factors in human nutrition, the "sparks," as McCarrison has styled them, which enable the human engine to liberate its energy with maximum efficiency.

Section 5

VITAMIN E

In the issue of the *Journal of the American Medical Association* for September 15, 1923, appeared an article by Evans and Bishop, whose opening sentences are as follows: "If female rats are reared on the now well known 'synthetic' nutritive regimen consisting of fat, carbohydrate and protein in relativly pure, separate form, to which are added an appropriate salt mixture and daily doses of the vitamins A and B, normal growth and every appearance of health result. The animals are of splendid size, sleek-coated and active. Depending somewhat on the season of the year, either a large proportion or, indeed, practically all of such animals are sterile. . . . The sterility produced is a dietary

deficiency disease, and can be quickly cured by a change of dietary regimen. It yields a highly characteristic picture, the chief features of which are the occurrence of apparently normal estrus and ovulation and the fertilization and implantation of the developing ova, but invariably disease and resorption of the products of conception.

"It at first occurred to us as possible that we had discovered in the rat a need for the antiscorbutic vitamin C which was not evidenced in any other way in this animal. In order to test the point, the basic dietary regimen was supported by the daily administration of orange juice in one series of experiments and by lettuce leaves in another series. Only one gestation out of five or six was successful with the orange juice regimen, but every individual tested produced litters of healthy young when fresh green lettuce leaves had been added to the dietary. It thus seemed apparent that we were in the presence of a new member of the 'vitamin' substances, or specific dietary needs, which we have provisionally designated by the letter X or as the antisterility factor."

In view of these authors' notable studies of the relations of vitamins A and B to reproduction, their findings were at once regarded as highly significant; as the work progressed, and the original view was confirmed, the new food factor was given the designation "vitamin E."

As the true nature of vitamin D was at first obscure owing to the numerous different ways in which rickets appeared to be preventable, so the existence of vitamin E was not suspected until there had been much re-

search on the whole reproductive process and many studies of fertility on different types of diet. The need of another factor besides vitamins A and B was the less readily perceived because of a transitory period of fertility following the attainment of sexual maturity, as shown with the animals on the orange juice ration above. But on a ration of purified casein, cornstarch, lard, butter fat, mineral salts, and yeast, sterility was exhibited sooner or later. By mating females whose fertility it was sought to investigate only with males of known fertility, and by following the complete sexual history of the animals, it was found that all of the early steps in the gestation process were accomplished, a normal number of eggs were fertilized and implanted, but the expected young were never born.

The embryos seem at first normal, but often by the eighth [1] day retardation in development can be observed, and at some time between the twelfth and twentieth day fetal death occurs, followed by resorption of the fetus. In no other type of dietary deficiency does this peculiar failure of placental function occur. When the existence of typical "resorption gestations" had been established, prompt restoration of fertility with as little as 10 grams of fresh green lettuce, resulting in the birth of healthy young, was strong presumptive evidence that the disease was of dietary origin.

Changes in the character of the protein of the diet and increases in the amounts of vitamins A and B were unavailing, and the possible influence of vitamin C was ruled out by the finding that a heated and dried powder of lettuce leaves, certainly devoid of C, was

[1] The normal gestation period in the rat is 21 days.

curative. White patent flour was found ineffective, even when constituting one-third by weight of the

Fig. 49.—A Rat Mother Three Months Old and a Litter Ten Days Old.

total ration, but careful work with wheat embryo revealed a remarkable potency of this substance, as little as one-fourth of a gram daily restoring normal

fertility. As these experiments were extended to other food materials, it became fully established that "resorption gestation" signified a dietary deficiency disease, due to the lack of a specific factor, vitamin E. It affects males as well as females, causing in the former destruction of the germ cells. A considerable amount can be stored, animals reared on diets capable of producing fertility remaining fertile three or four months after the vitamin is removed from the diet.

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CHAPTER X

FOOD AS REGULATING MATERIAL
THE VITAMINS

Part II

THE FUNCTIONS AND THE SOURCES OF THE VITAMINS

Although chemical study of the vitamins has not yet attained its ultimate goal—knowledge of the chemical constitution of each of the five now definitely known to exist—it has provided the tools for investigating their functions in nutrition and their distribution in food materials and given us much information regarding both.

By withholding a single vitamin from an otherwise adequate diet, its more striking functions are readily discovered. By partial deprivation the subject may be kept alive for study over a longer period, and thus other functions brought more plainly into view. Animals which can be studied from generation to generation must be used to get a true perspective on the influence of diet, inasmuch as one seemingly good for the adult may prove quite inadequate for bearing and rearing young, or these processes may be carried out at undue cost to the mother. While various animals have been useful in different phases of vitamin study, the quickly growing, omnivorous and prolific white rat, living healthily in restricted quarters, may now be regarded as a standard testing agent in nutrition. The long span of human life gives us little opportunity

to gain a perspective on factors operating very slowly and subtly, so we make progress by substituting a life only one-thirtieth as long, one day in the life of the rat being as one month in the life of a man; one year as thirty years. In a few weeks we may know whether a given diet is doing good or harm, and in a year or two we may chart the progress of a family through several generations.

Such work teaches us what to look for in studying the problems of human nutrition. Two of the most widespread nutritional diseases of the human race, beriberi and scurvy, were conquered when it was found possible to induce the same diseases in animals by dietary measures and to demonstrate their cure by appropriate changes in the food supply.

As knowledge has accumulated and methods of research have become more refined, it has been found that the significance of the vitamins transcends the mere prevention of a specific disease; it now extends to the daily life of every individual and may determine whether his life be lived on a low nutritional plane or a high one. What has been learned with regard to the functions of each vitamin will be discussed in the following pages.

Section I

VITAMIN A

The Prevention and Cure of Xerophthalmia

The discovery of vitamin A did not come about through search for a cure for disease, as did that of the vitamins B and C. But as soon as vitamin A was recognized as a definite factor in growth (1913) and experi-

ments to determine the effect of withholding it from the diet were initiated, the observation was frequently made that the animals developed a characteristic eye disease. In this the lachrymal gland ceases to function; the eyeball becomes dry and bacteria quickly begin to grow in the conjunctival sac; the lids of one or both eyes become congested, an exudate comes from the inflamed conjunctiva; and soon the swollen, sticky and scabby lids completely close the eye. If not arrested, the disease eventually attacks the cornea and permanent blindness ensues, unless the animal die before this stage be reached. This disease is variously known as ophthalmia, xerophthalmia, keratomalacia, or conjunctivitis. The relation of the diet to the disease was discovered by Osborne and Mendel, who wrote in 1913: "A type of nutritive deficiency exemplified in a form of infectious disease prevalent in animals inappropriately fed is speedily alleviated by the introduction of butter-fat into the experimental rations."[1] In 1921, reviewing their experiences with this disease, they gave the following report of practically all the rats under observation in their laboratory for one year.

INCIDENCE OF XEROPHTHALMIA IN 1,000 RATS

	Total Number of Rats	Number with Eye Symptoms
On diets deficient in vitamin A	136	69
On diets deficient in vitamin B	225	0
On diets otherwise deficient	90	0
On diets experimental but presumably adequate	201	0
On mixed food (stock animals)	348	0
	1,000	69

[1] Osborne, T. B., and Mendel, L. B. "The Relation of Growth to the Chemical Constituents of the Diet." *Journal of Biological Chemistry*, Vol. 15, page 311 (1913).

"It should be added," they remarked, "that in observations on several thousands of rats, we have never observed distinct symptoms of comparable eye disease in any animals except those which had experienced a deficiency of fat-soluble vitamin in their diet." [1]

These laboratory experiences with the white rat

(Courtesy of Doctors Osborne and Mendel)

Fig. 50.—Xerophthalmia in the Rat.

stimulated inquiry as to the effect of withholding the A vitamin from other species of animals, and xerophthalmia has been experimentally produced in dogs, rabbits, mice, horses, swine, guinea pigs, chickens, and monkeys.

Such experiences inevitably turned attention to eye

[1] Osborne, T. B., and Mendel, L. B. "Ophthalmia and Diet." *Journal of the American Medical Association*, Vol. 76, page 905 (1921).

disease occurring in the human race, with a view to its possible correlation with dietary deficiency. Apparently the first person to suggest a connection between human xerophthalmia and diet was a Japanese physician named Mori, who published in German a report of the

(*Courtesy of Doctors Steenbock, Nelson and Hart*)

FIG. 51.—Xerophthalmia in the Dog.

so-called "Hikan," an eye disease of which, at a time of food storage, he had observed nearly 1,500 cases among children from two to five years of age. This he believed to be due to the lack of fat, as it was curable (if it had not progressed too far) by the administration of chicken livers, fish livers, or eel fat, and also of cod-liver oil, all of which are rich in vitamin A.

Other illuminating experiences were recounted thirteen years later (1917) by Dr. C. E. Bloch [1] of Copenhagen, who had personally observed during the years from 1912 to 1916 many cases of xerophthalmia among children of the Danish poor. The most severe cases were among children about a year old, who had been fed chiefly skimmed milk practically free from fat, along with oatmeal and barley soup, and who were threatened with blindness owing to ulceration of the cornea. As the children were greatly undernourished, whole milk was prescribed together with liberal doses of cod-liver oil. The result was a rapid disappearance of the eye trouble and a complete cure whenever the destruction of the cornea had not gone too far. In 1918, upon the introduction by government action of butter into the dietary of the poorer people, xerophthalmia was practically wiped out of Denmark.

During the World War Professor H. Gideon Wells, of the University of Chicago, found in Roumania children suffering from eye trouble which could be cured by cod-liver oil, and Dr. E. J. Dalyell, of the Lister Institute in London, had a similar experience in Vienna. There seems to be little reason to doubt that these children were suffering from a lack of vitamin A in their diet.

Night blindness is another form of eye disease, closely associated with xerophthalmia, which appears to be likewise due to a deficiency of vitamin A in the diet. It has been observed among prisoners on long sea voyages; among coolies and soldiers in India, China, and Japan; among Russians during their Lenten fasts; among

[1] Bloch, C. E. "Eye Disease and Other Disturbances in Infants with Deficiency of Fats in the Food." *Journal of the American Medical Association*, Vol. 68, page 1516 (1917).

Austrian prisoners of war in Russia; among negro slaves in Brazil on a diet restricted to beans, pork fat, and maize meal; and among the inhabitants of Newfoundland and Labrador, whose winter and spring diet consists largely of white wheat bread, dried peas, and salt meat.

Bitol, who is said to have been the first to describe

(*Courtesy of Dr. V. E. Nelson*)

Fig. 52.—Xerophthalmia in the Rabbit. The eye disease developed in the mother (right) as the result of bearing the young on a ration deficient in Vitamin A.

xerophthalmia, in 1863, found all of his 29 cases suffering from night blindness. Blegvad, in an investigation for the Danish Ophthalmological Society, reported in 1923 that out of 66 xerophthalmia patients over three years of age 37 manifested night blindness. The development of this disease in rats by withholding vitamin A from the diet has been studied by Fridericia and Holm,[1] of the University Institute of Hygiene in Copenhagen, who found that young rats kept for three

[1] Fridericia, L. S., and Holm, Eiler. "Experimental Contribution to the Study of the Relation Between Night Blindness and Malnutrition." *American Journal of Physiology*, Vol. 73, page 63 (1925).

weeks on a diet devoid of vitamin A began to manifest symptoms of eye disturbance, although showing no sign as yet of corneal infection; they would frequently sit still, with half-closed eyes turned away from the light, while other animals on a normal diet moved freely about. In the early stages of xerophthalmia exposure

(*Courtesy of Dr. C. E. Bloch*)

FIG. 53.—A Baby with Severe Xerophthalmia. The left eye is swollen shut. A corneal ulcer destroyed the sight of the right eye.

to intense light reveals a defect in the visual purple of the rod cells of the retina whereby its regeneration after being normally bleached by light is prevented; without such regeneration vision at faint illumination becomes impossible. That night blindness is due to lack of vitamin A seems evident from its being cured in rats in two or three days by a diet rich in vitamin A.

The occurrence of night blindness only under certain

circumstances would seem to be explained by the fact that it develops on exposure to intense light. In Labrador it follows long exposure to the dazzling glare of sun and snow, and in India troubles soldiers and coolies in the long twilight following the blaze of the hot midday sun. Night blindness and xerophthalmia seem, therefore, to have a common origin in an infection to which the eye is rendered susceptible on account of lack of vitamin A in the diet. Because of its power to cure xerophthalmia, vitamin A is frequently referred to as the anti-xerophthalmic or antiophthalmic vitamin. This term, however, indicates but one phase of its importance in nutrition.

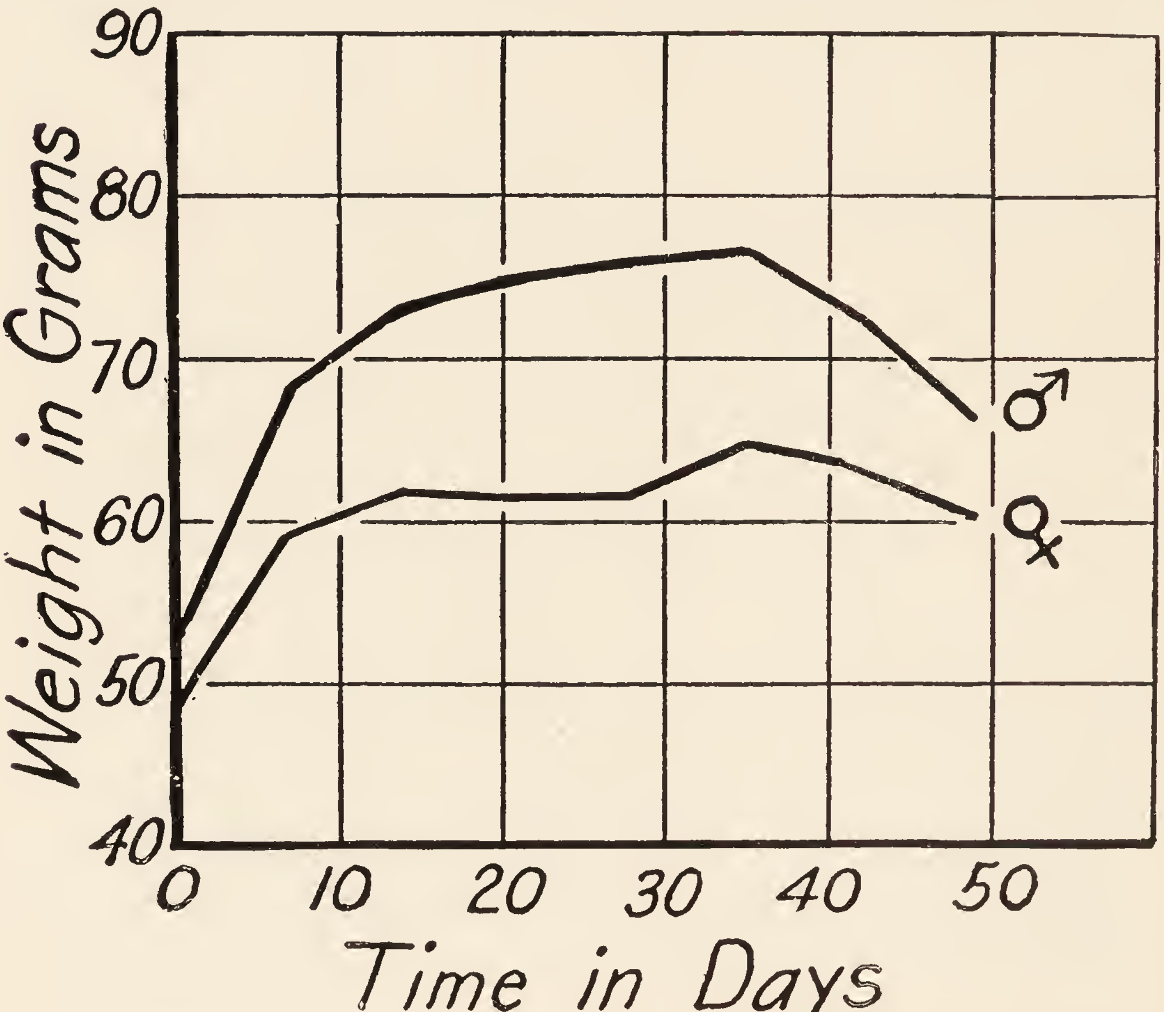
The Promotion of Growth

As has already been recounted, vitamin A was discovered through the failure of rats to grow for more than 70 to 120 days on rations adequate in protein, mineral salts, and vitamin B, and their prompt resumption of growth when butter fat or an ether extract of egg yolk was added to the ration. At first there was much irregularity in the time required by different animals to manifest symptoms of vitamin A deficiency, but it was soon realized that if the animals placed upon the A-free diet had been previously fed one rich in it, they continued to grow for a much longer time than those whose former diet had been good in all other respects but low in vitamin A. Typical growth curves for young rats, weaned at the age of four weeks from a mother on an adequate diet, and placed on a diet entirely free from vitamin A, show how definitely it is possible to predict the time when growth will cease and death ensue.

At first growth is good because of stores of vitamin

A derived from the mother. Between the thirtieth and the fortieth day growth ceases, a decline in weight sets in, and in about sixty days death ensues.

The control of the rate of growth by varying the



(*Courtesy of Dr. Hazel E. Munsell*)

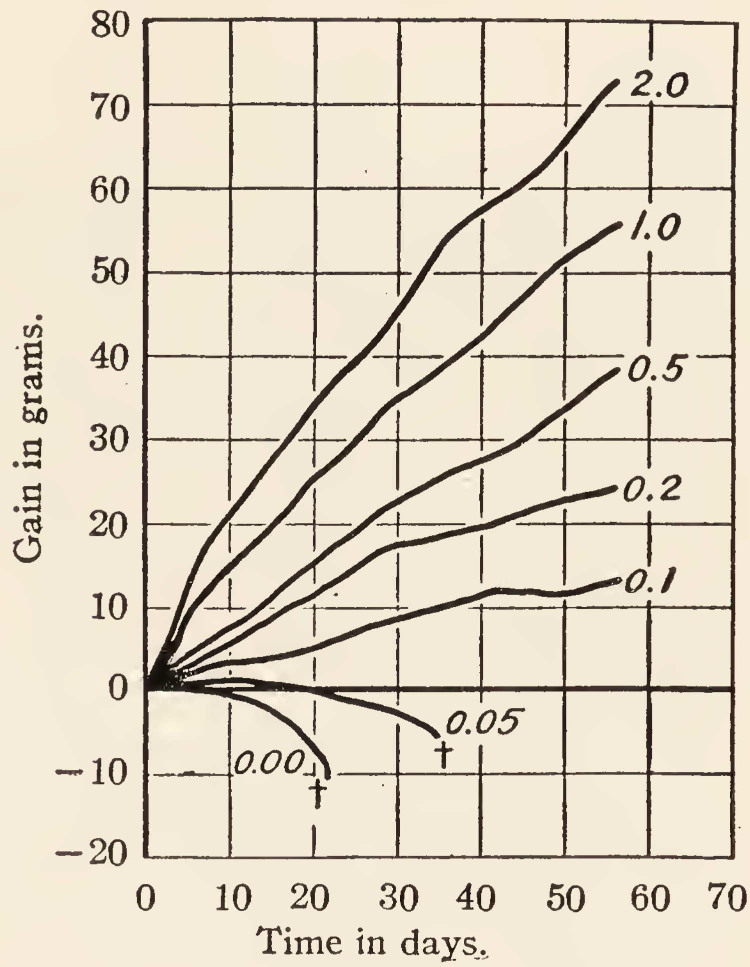
Fig. 54.—Rats placed at weaning time (28–29 days) on a diet devoid of vitamin A grow until the reserves of the vitamin in their bodies are exhausted, after which they decline in weight and die. Each curve above represents the average of thirteen rats.

amount of vitamin A is further evidence of the very direct control which this vitamin exerts over the development of the young. (Fig. 55.)

Reproduction

After vitamin B had been discovered and attempts were being made to rear animals on diets of purified

casein, lard, cornstarch, and mineral salts to which a daily portion of yeast was added for vitamin B, it was found that, while the young animals grew for some time at a good rate, they matured late and were frequently sterile or else bore offspring so feeble that they soon died. This type of diet contained little if any vitamin A. Upon the discovery of the existence of vitamin A and the substitution of butter fat for part of the lard, it became possible not only to secure growth to full maturity but also to obtain a second generation of animals and bring them, too, to successful reproduction.

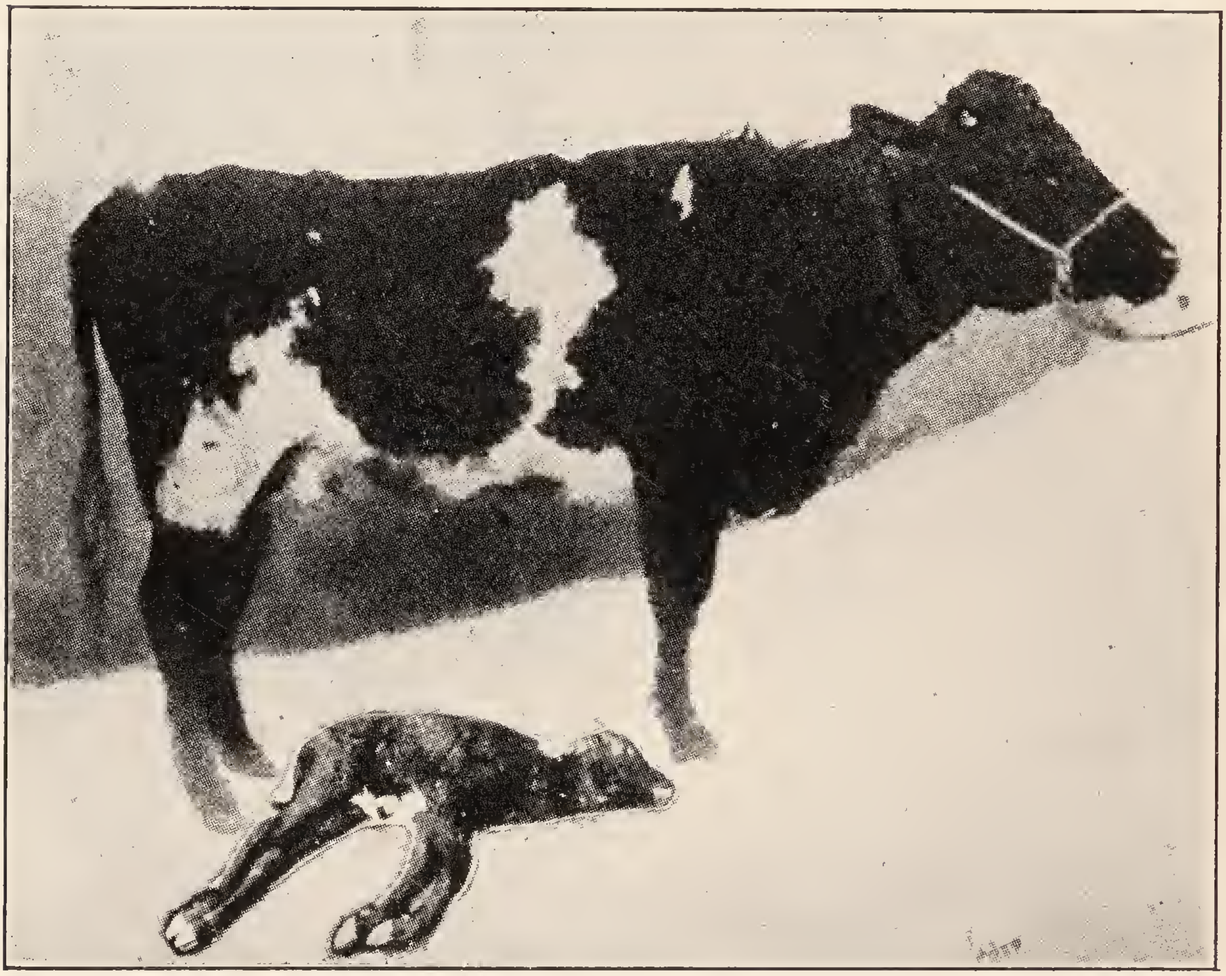


(*Courtesy of Doctors H. C. Sherman and H. E. Munsell*)

FIG. 55.—Differences in rate of growth due to differences in the intake of vitamin A. The figures at the end of the curve indicate the number of grams of tomato fed as the source.

In the classic Wisconsin experiment with rations derived from a single plant source, the most unexpected result was the difference in the reproductive capacity of the cattle on the different diets. Normal young could not be produced on the wheat-plant ration; the estrus cycle was delayed and in some individuals never appeared. Where the estrus cycle did appear, the offspring were stillborn or

died soon after birth. On the corn ration the reproduction cycle was complete, and where yellow corn grain was substituted for the wheat grain in the wheat plant ration, to which a mineral salt mixture contain-



(*From Research Bulletin 17, University of Wisconsin Agricultural Experiment Station*)

FIG. 56.—In 1907, feeding a ration made from wheat straw, wheat meal and wheat gluten, with common salt, resulted in nutritional disaster. The cow was shaggy-coated, slow and sleepy in movement, and had a tendency to drag her hind feet. The calf was born prematurely and died.

ing calcium had been added, reproduction again became normal. It was not then known that yellow corn contained vitamin A.

In 1924, the Wisconsin experimenters rebalanced the wheat plant ration and corrected its deficiencies in the light of our present knowledge. To the original

ration of wheat meal, wheat gluten, and wheat straw, they added 2 per cent of bone meal for calcium phosphate, 1 per cent of common salt (as wheat is low in chlorine), and 2 per cent of raw cod-liver oil. No more beautiful demonstration of the triumph of dietary

(Courtesy of Doctors Hart and Steenbock)

FIG. 57.—In 1924, when the ration of 1907 was supplemented with bone meal 2 per cent, common salt 1 per cent, and raw cod-liver oil 2 per cent, its deficiencies were fully corrected. This cow was in excellent condition and produced twins weighing 124 pounds.

knowledge can be found than in the contrast between the wheat-fed cow and calf of 1907 and those of 1924.

The way in which vitamin A functions in reproduction has been made the subject of special investigation by Evans and his associates in the Department of Anatomy of the University of California, who find that a characteristic disturbance of the estrual cycle with

consequent failure of ovulation occurs in 100 per cent of animals reared on diets low in vitamin A and yet containing enough to permit approximately normal growth. "It was apparent, then," Evans remarks, "that we had a new and more sensitive test for physiologic well-being than that furnished by either growth, glossy coats, bodily activity, or the other easily detected signs."[1]

The interference with reproduction caused by lack of vitamin A is unlike that brought on by any other kind of dietary deficiency, and is cured by raising the amount of A to a higher level. This has been demonstrated by Sherman and MacLeod, who took two groups of rats from mothers on an adequate diet and fed them diets alike in all other respects, but one low, the other high in vitamin A. The diet with the lesser amount of A proved sufficient for normal growth up to nearly average adult size, but not for successful reproduction. The animals receiving the more liberal allowance of vitamin A grew to fully average adult size, and their success in reproduction is admirably typified by a comparison of twin sisters on the two diets, as shown on page 101.

Longevity and Resistance to Infection

The ability of the animal body to store vitamin A at practically all ages has been clearly shown by Sherman, who from the vantage point of "personal acquaintance with over ten thousand rats" emphatically states that a surplus of vitamin A in the body is not

[1] Evans, H. M. "The Relations Between Fertility and Nutrition." *Lectures on Nutrition of the Mayo Foundation*, page 214 (1925).

simply a reserve for some future time of shortage, but is at all times significant for the maintenance of resistance to disease and a high level of physical vigor. In many ways evidence has become convincing that a diet poor in vitamin A increases susceptibility to certain kinds of disease of bacterial origin.

We have seen how young rats placed at weaning

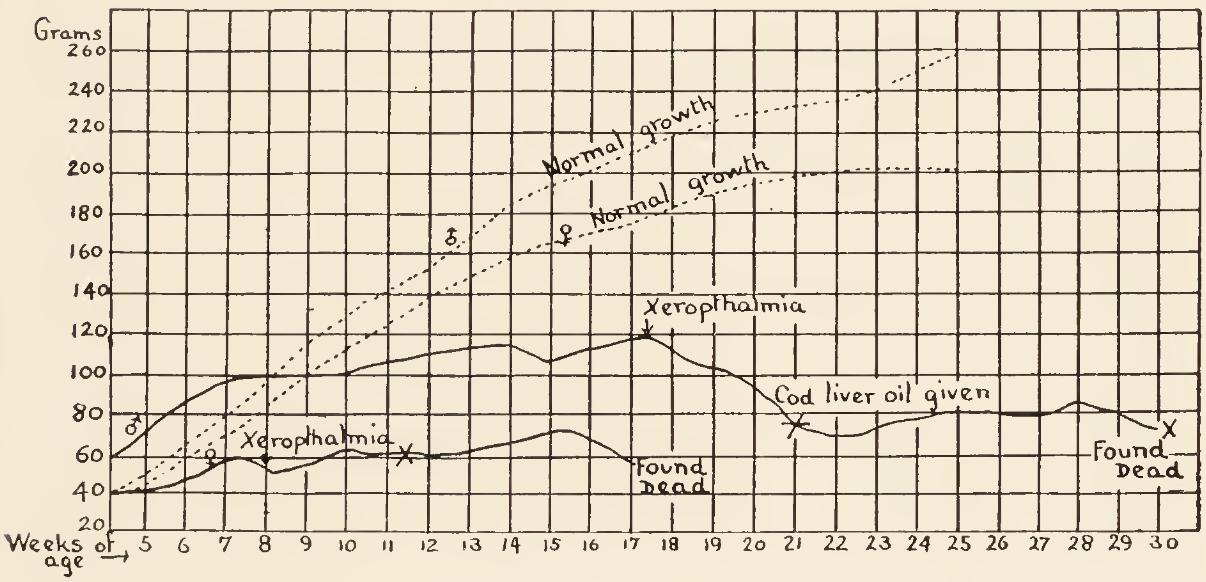


FIG. 58.—Growth records of twin brother and sister rats showing difference in resistance to deprivation of vitamin A. Note that the larger and stronger male did not develop xerophthalmia nor succumb to death as soon as the female, but that in both cases the general trend is the same, and that even cod-liver oil could not save the male when a decline finally set in. For a picture of a xerophthalmic rat see page 240.

time on a diet devoid of vitamin A generally develop xerophthalmia before death, which occurs quite regularly at about the age of 60 days. Once in a while an animal, more hardy by nature than the average, will resist the eye disease and remain alive for a much longer time. The graph above gives the growth record of one such case, a male rat whose twin sister, weaned at the age of four weeks and put on a diet devoid of vitamin A, showed swollen eyelids at the age of 11 weeks. While

he continued to grow slowly for many weeks more, and seemed to be living in defiance of the laws of nutrition. Yet in 17 weeks he had used up the food reserve acquired from his mother and developed one sore eye. Even then he did not immediately decline to the point of death, but continued to live for a month, underweight, rough and dirty of coat, half blind, weak and miserable, a striking instance of vigorous youth coming to a wretched middle life and failing to live to the good old age to which his original vigor predestined him. At the age of twenty-one weeks he was given cod-liver oil, which kept him alive for two months more, but he was finally found dead; the better diet had come too late to save him.

At autopsy such an animal will generally reveal some pathologic disturbance not outwardly discernible. The low capacity to resist infection when the tissues are not well stored with reserves of vitamin A manifests itself in a great variety of ways. Very often there will be found a pus sac in one or more of the glands near the base of the tongue. Munsell found in one hundred autopsies of young rats dying from lack of vitamin A fully three-fourths showing these pus sacs. This condition has not been found in any rat on a diet deficient in vitamin B only, nor in any rat on a normal diet.

Osborne and Mendel have found bladder stones in experimental animals kept for some time without an adequate supply of vitamin A, and attribute these to local bladder infection to which the lining membrane becomes susceptible when this vitamin is lacking. Daniels has found in cases of young rats placed at four

or five weeks of age on a diet low in vitamin A frequent loss of appetite, snuffles, and labored breathing. When animals kept from eight to ten weeks on this ration were examined at autopsy, without exception the nasal sinuses and middle ears were filled with pus. Mori has found the larynx of rats with xerophthalmia also implicated in the pathologic process, and a similar condition in children suffering from the eye disease, who, like the rats, frequently die from bronchial pneumonia.

Rats two or more months of age when placed on a diet lacking vitamin A are less susceptible to xerophthalmia than younger ones, but this does not mean that they no longer stand in need of the vitamin, for they now manifest a marked susceptibility to lung infection. Sherman and MacLeod found in their series on diets low and high in vitamin A, that on the former, along with failure to reproduce, there developed in early adult life a tendency to break down with lung disease at an age corresponding to that at which pulmonary tuberculosis so often develops in young men and women; and Sherman and Boynton have shown that animals whose diet has been relatively poor in vitamin A actually have less of the vitamin in their lungs than animals liberally supplied with it. Moderate differences in the vitamin A content of the food result in distinct differences in the amount stored in the lung tissues. There seems to be no doubt that the presence of a store of vitamin A in the lungs makes them more resistant to disease. Evans suggests that the disturbance of the mucous membrane of the vagina which seems to be responsible for the disturbance of the estrual cycle on diets low in A is akin to the xerosis which

attacks the mucous membrane of the eye. Very significant is the finding of Sherman and his associates that young female rats growing normally and presenting every appearance of good health throughout youth on a diet low in vitamin A not only failed to succeed in the rearing of offspring, but themselves showed a tendency to lose their health at the very age when they should have been most fit.

Even when enough of this vitamin is provided to bring young animals to normal adult size without any visible signs of disease and to permit them to have several litters of young, there will be clear indications that they could profitably use a much larger supply. Thus Sherman and MacLeod found that their animals receiving the more liberal allowance of A lived on the average a little over twice as long as those on a diet equally good in other respects, but lower in vitamin A. Taking two strictly comparable sets of animals, they found that 22 rats with the lower supply of vitamin A died at an age averaging 369 days, corresponding to about thirty years of human life, while of 22 rats with the larger supply there was one still living at the close of the experiment, and the average of all living and dead was then 740 days, corresponding to about 60 years of human life.

In the light of our present knowledge of the great importance of this vitamin throughout the whole life-time of the individual, from infancy to old age, it behooves us to see that it is at all times liberally supplied. And since the body seems to have unusual power to store it in the tissues, where it becomes a safeguard against insidious forms of bacterial

disease and a promoter of health and vigor at all ages, the constant use of foods which are known to be rich in it should be regarded as a wise form of health insurance.

Section 2

VITAMIN B

Prevention and Cure of Beriberi and Polyneuritis

Vitamin B was at first called the "beriberi vitamin" because of its power to prevent or cure this disease, which has been a scourge in various parts of the world where polished rice has constituted a large proportion of the diet. It is a form of nerve degeneration in which the nerves of motion and sensation are affected. Progress in its cure dates from Eijkman's discovery in 1897 that a similar illness could be induced in fowls. Prompt alleviation of the nerve symptoms follows administration of vitamin B.

Investigations on the effect of a diet of polished rice were quickly extended to other laboratory animals, and it was found that mice generally died in ten to fifteen days when fed exclusively on polished rice, while if given an extract of the rice bran they lived much longer. So, too, dogs fed cooked polished rice and the boiled-out residue of horseflesh for two or three weeks began to lose appetite and declined greatly in body weight in the course of five to seven weeks; but, again, a very little of the rice bran extract would effect a cure in a few days, even though the animals seemed on the verge of death.

Promotion of Growth

Almost simultaneously with the discovery of an antineuritic substance which could be separated from food materials came the discovery of the growth-promoting properties of "water-soluble B" and the view that the antineuritic and growth-promoting properties are attributes of the same substance. Even in the early experiments on the production of polyneuritis

A B

Fig. 59.—These two rats are the same age (8 weeks). The one on the right has had an adequate diet, the one on the left a diet lacking vitamin B.

in pigeons, it was noted that of two pairs with no difference in diet save that one pair had added vitamin, the difference in growth was astonishing. In ten to fifteen days the pair without the vitamin suffered a great loss in weight while the other pair showed a gain.

If we wean a young rat at the age of 28 days, from a mother on an adequate diet, and give it a diet furnishing everything needed for growth save vitamin B, we shall get a characteristic growth curve as shown above, and in four weeks it will be so weak and miserable that death will promptly ensue unless the diet is changed. Giving such a rat daily one gram of compressed yeast,

rich in vitamin B, will produce signs of returning health in a few hours and growth will be resumed at once.

Maintenance of Appetite

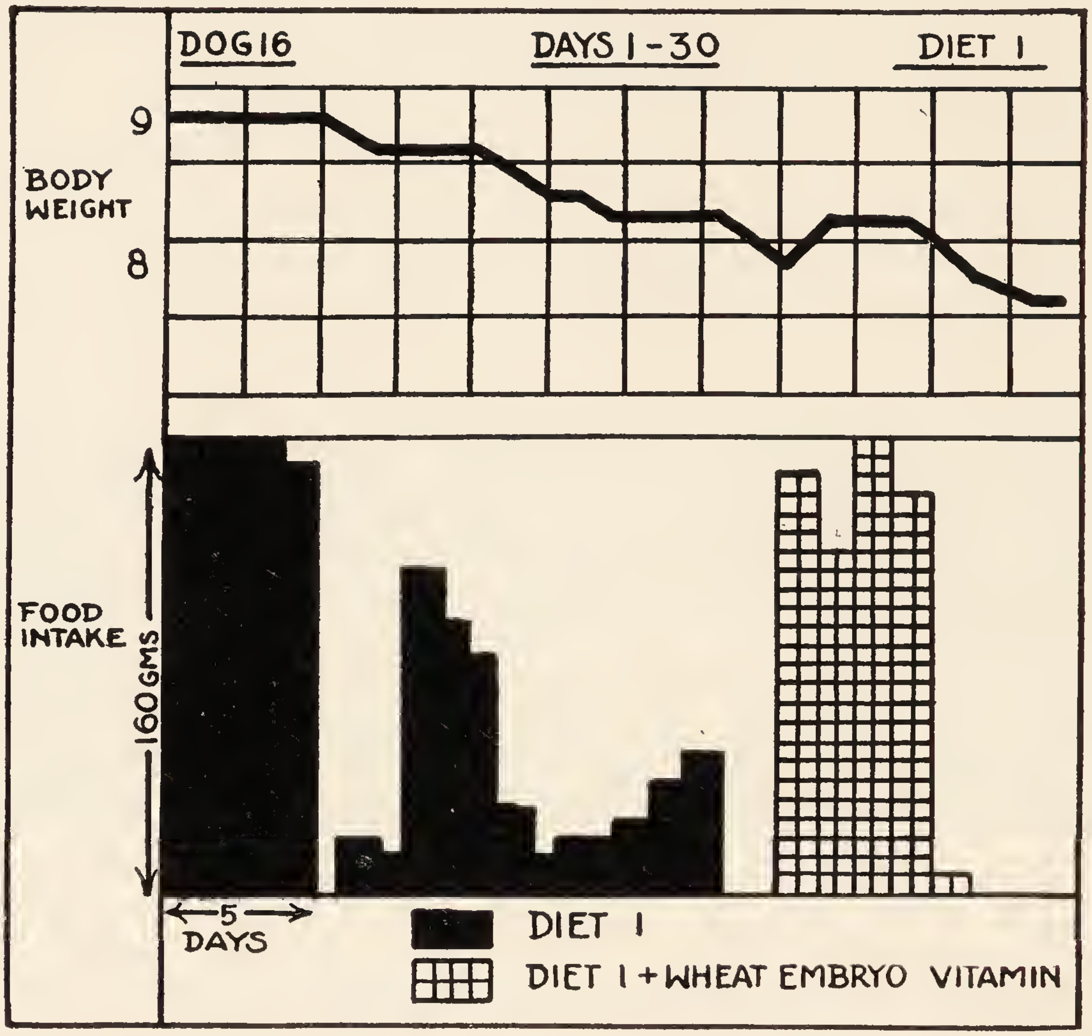
The loss of weight in young animals deprived of vitamin B results in their death before they have time to develop symptoms of polyneuritis. Older animals will live for a much longer time and die with marked signs of the nerve disease. Study of the food intake of these animals gives an explanation of the difference in length of life. The food intake of animal A in Fig. 59, as compared with animal B, the normal control, is shown in the table below.

Food Consumption of a Pair of Rats Placed at Weaning Time on a Normal Diet, Compared with that of a Similar Pair given a Diet Lacking Vitamin B

DATE	WEIGHTS OF RATS GRAMS		FOOD INTAKE PER GRAM OF RAT PER DAY GRAMS	WEIGHTS OF RATS GRAMS		FOOD INTAKE PER GRAM OF RAT PER DAY GRAMS
	Male (*A*)	*Female*		*Male* (*B*)	*Female*	
June 30	38	36	—	38	33	—
July 7	41	42	0.065	61	43	0.081
" 14	43	45	0.050	82	54	0.092
" 21	39	41	0.039	89	66	0.073
" 28	37	39	0.030	104	74	0.058
Aug. 4	35	36	0.019	110	78	0.042
" 11	29	Dead	0.016	126	87	0.052

We see, therefore, that a lack of vitamin B in the diet of the rat speedily affects appetite. The same is true of the dog. Dr. George R. Cowgill, of Yale University, has shown that the dog will in the course of a week develop a fitful appetite, insufficient to maintain body weight, on a diet adequate in all respects save this vitamin, even though eating well at first. This is

illustrated in Fig. 60, in which the solid black part represents the intake on the diet without the vitamin



(*Courtesy of Dr. George R. Cowgill*)

FIG. 60.—Showing loss of appetite of a dog on a diet lacking only vitamin B, and recovery of appetite upon administration of the vitamin. The solid black part represents the intake on the diet without the B vitamin. For the first five days the intake was up to the animal's requirement; then a day was skipped, followed by several days of poor intake, partial recovery of appetite, a fall again, a poorer recovery, and finally two days without taking any food. At this point vitamin B was administered, and the checked block represents the subsequent food intake, a nearly normal appetite developing at once.

and the checked part that when vitamin B was added.[1]

[1] Cowgill, G. R. "A Contribution to the Study of the Relation between Vitamin B and the Nutrition of the Dog." *American Journal of Physiology*, Vol. 57, page 42 (1921).

Ten animals responded in this fashion. In two cases, food which was refused in the morning was eaten with alacrity in the afternoon, several hours after administration of vitamin B.

Cowgill has also found that beef extract, long thought desirable for stimulating the appetite, is without any effect in inducing animals to eat when they have refused on account of lack of vitamin B. He says, "In every case, after a definite failure of the beef extract either to restore or to maintain the appetite had been demonstrated, vitamin B was given and a positive stimulation of the desire to eat obtained." [1]

Relation to General Health

The loss of appetite on diets poor in vitamin B is undoubtedly related to disturbances in the stomach and intestines which interfere with the digestion and absorption of food. Animals killed in polyneuritis sometimes have the stomach full of undigested food, and food remains in the crop of polyneuritic pigeons and chickens. An amount of vitamin B which will prevent disturbance of the nervous system may still be insufficient to maintain the health of the alimentary tract. Dr. Robert McCarrison, of the British Medical Service in India, has made very extensive studies of the effects of vitamin B deficiency, and finds impaired production of the digestive juices, congestion of lining membranes resulting in chronic gastrointestinal catarrh, and marked impairment of the neuromuscular control of the

[1] Cowgill, G. R., Deuel, H. J., and Smith, A. H. "Studies in the Physiology of Vitamins. III. Quantitative Aspects of the Relation Between Vitamin B and Appetite in the Dog." *American Journal of Physiology*, Vol. 73, page 115 (1925).

intestine among the many conditions detrimental to nutrition which develop when vitamin B is fed in insufficient quantity.

Such conditions not only cause loss of appetite and failure of digestion and absorption, but make the intestine less capable of protecting itself against bacterial infection. Besides the derangement of the functions of digestion and assimilation, there are degenerative changes in various organs, such as heart, liver, and kidney, and in important glands, as pancreas, thyroid, and especially the adrenals, all of which must be deleterious to health. If the deficit in B vitamin is only partial, nervous symptoms may be entirely absent, and only loss of weight, weakness, dyspepsia and intestinal troubles give evidence of the inadequacy of the diet.

Reproduction

In their studies of reproduction in the rat, Evans and Bishop found that when vitamin B is withheld from the diet the animals not only lose weight rapidly but exhibit no œstrus cycles. Upon addition of vitamin B, they gain weight rapidly but there is no ovulation for some time. McCarrison has emphasized degenerative changes in the ovary and the testes of animals fed diets lacking in B, which would lead to sterility in both sexes; and similar findings of other investigators amply justify the conclusion that successful reproduction and lactation demand a greater supply of this vitamin than is necessary for growth or the maintenance of health.

Section 3

VITAMIN C

The Prevention and Cure of Scurvy

The discovery of vitamin C was brought about by the search for a cure from scurvy, which has been styled "the most clear-cut and sharply defined nutritional disease." The species whose susceptibility to scurvy is best known are the guinea pig, monkey, and man. As early as 1895, Dr. Theobald Smith, of the Rockefeller Institute for Medical Research, noted that guinea pigs kept upon a diet of oats developed a hemorrhagic disease, but this observation was entirely disregarded at that time. It was only after Holst and Frölich began to publish their work with guinea pigs (1912) that the close resemblance between scurvy in these animals and in man was established, and the search for a vitamin in the foods which were known to cure it vigorously prosecuted.

Fig. 61.—A Normal Guinea Pig.

Some skepticism as to the existence of a specific dietary factor arose from the fact that the rat, most widely used for vitamin study, does not develop scurvy. It has since been found that rats' livers contain the

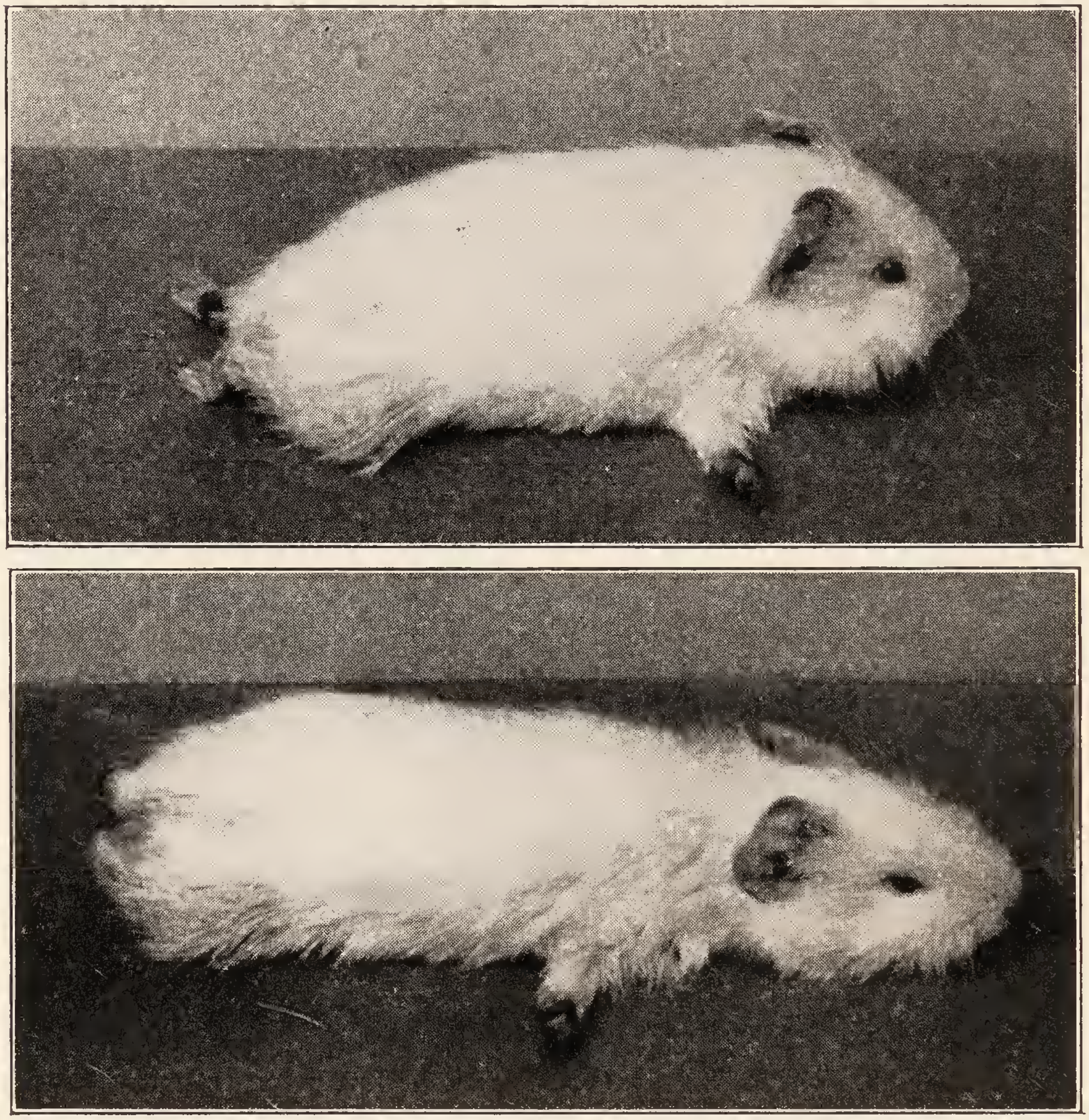
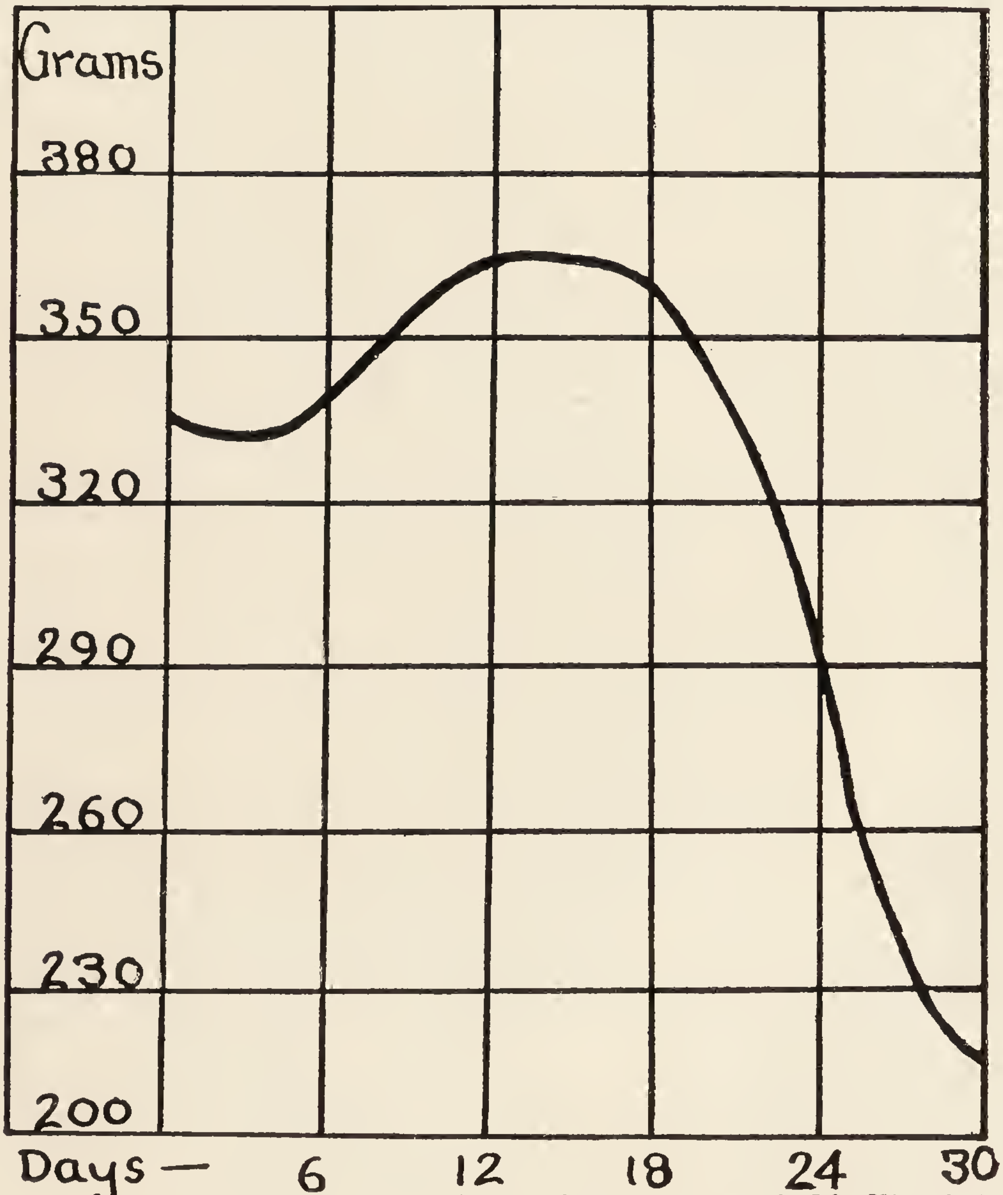


Fig. 62.—Two Characteristic Positions of a Scorbutic Guinea Pig.

antiscorbutic vitamin even though the animals have been fed for a long time on rations devoid of it. According to Parsons, who discovered this fact, "It is conceivable that the rat has acquired not only a lower requirement, but also a phenomenal capacity

to store the antiscorbutic substance through a biological adaptation to a food supply which over long periods of time is very deficient in this substance." [1]



(*From Sherman and Smith, The Vitamins*)

FIG. 63.—Guinea pigs six to eight weeks old and weighing 300 to 350 grams placed on a scorbutic diet continue to grow for about 15 days, then lose weight rapidly and die of scurvy in from 26 to 34 days. The above curve is the average of 10 guinea pigs on a diet lacking vitamin C.

Whatever the ultimate explanation, the study of the C vitamin requires as a "testing agent" an animal

[1] Parsons, H. T., and Hutton, M. K. "Some Further Observations Concerning the Antiscorbutic Requirement of the Rat." *Journal of Biological Chemistry*, Vol. 59, page 97 (1923).

(*Courtesy of Dr. Percy R. Howe*)

Fig. 64.—A guinea-pig's jaw-bone, showing great erosion of the bone brought about by a diet lacking in vitamins. This is especially well seen in the portion below the back teeth.

readily susceptible to its absence, and the guinea pig is the most available. What happens when a guinea pig is put on a diet lacking in vitamin C is shown in Figs. 61, 62, 63. The weight falls steadily, the joints become tender, those of the limbs being involved first. There follows in a day or so a gradual swelling of the affected joints, often to two or three times the original diameter of the bone. Sometimes in the younger animals a joint will fracture spontaneously, the wrist being most susceptible. The older animals develop a difficulty in using their hind legs, which seem to become stiffened or paralyzed. The junctions of the ribs with the cartilages show "beads" similar to those in rickets. At first the animals eat well and gain in weight. Then follow a loss of appetite and a fall in weight, signs of great weakness, and death regularly in about 30 days. At autopsy the two most notable conditions are hemorrhages and fragility of the bones. The heart and the adrenal glands are enlarged, the teeth are loosened from their sockets and take irregular positions and in the case of young animals may be so decalcified that they can be bent with the fingers. Changes in the teeth may occur before other symptoms of scurvy are manifested. Prompt improvement follows administration of food rich in vitamin C, if the animals are not already moribund, and Dr. Percy R. Howe, Professor of Dental Research in Harvard University, has observed decalcification of the bone, as shown in Fig. 64.

Subacute or Latent Scurvy

While outbreaks of human scurvy may follow serious food shortages in war and famine, well-defined cases

are rare among adults in this country and only occasionally seen among children. Infants are more liable to it, since they may be fed for considerable periods on heated milk with only some carbohydrate supplement, receiving practically no vitamin C. Furthermore, Hess, in his wide experience with infants, has found that many who do not have acute scurvy suffer from irritability, lack of appetite, signs of anemia, general weakness and retardation of growth, which can be relieved by increasing the antiscorbutic food in the diet.

Since the teeth have been found to be one of the first parts of the body to be affected by a deficiency of vitamin C, and to be seriously affected when scurvy is scarcely suspected, there seems little doubt that the notoriously defective teeth of American children may in part be due to a lack of vitamin C in infancy and early childhood. The only safe course is to give every child at all times a suitable supply of antiscorbutic food.

Laboratory experiences with the white rat bear testimony to the fact that the absence of scurvy does not prove that the body is receiving all the vitamin C it can profitably use. Drummond and others have found that the addition of vitamin C in the form of orange juice to the diet of young rats results in better growth, even though they could grow to maturity without any specifically antiscorbutic food.

A condition of latent scurvy is not uncommon among adults. There is a reduced state of nutritional activity in all the tissues of the body. Dr. James Lind, whose classic account of his experiences with scurvy has already been referred to (page 214), noted "an uncommon

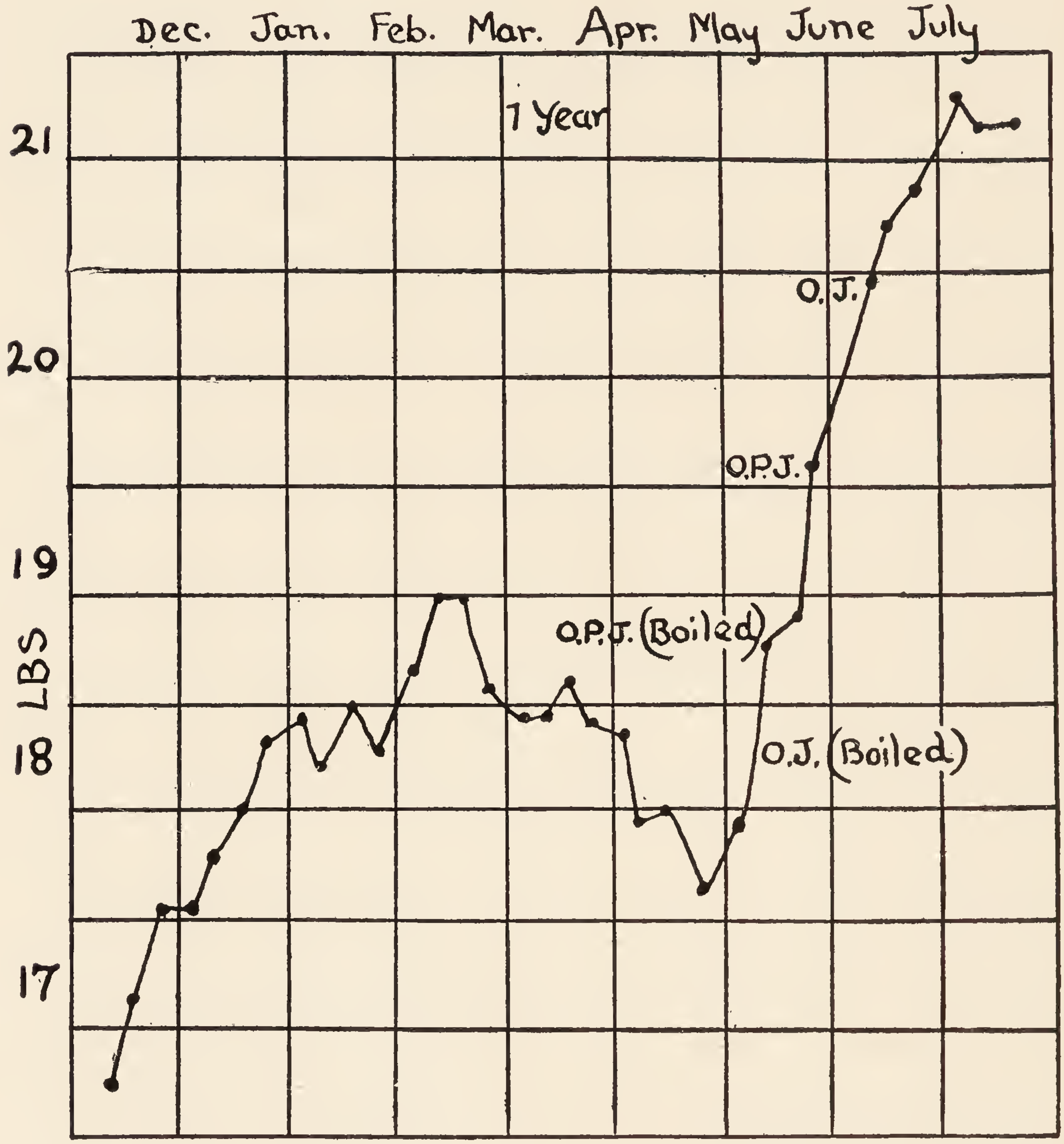
degree of sloth and laziness which constantly accompanies this evil," and Plimmer says that those who habitually take too little vitamin C have a low state of health, of which common symptoms are "a sallow, muddy complexion, loss of energy, fleeting pains in the joints and limbs, especially in the legs, usually mistaken for rheumatism." It has been shown by Findlay that power to resist common infection is increased by a liberal supply of vitamin C, while McCarrison says that a deficiency of this substance is likely to lead to congestion and hemorrhage in the alimentary tract in animals that have not during life manifested clinical symptoms of scurvy.

Even among people whose dietary does not seem particularly limited, there is need of some care lest the rather irregularly distributed and easily destroyed vitamin C fall below the optimum. The writer saw one case of adult scurvy in Bellevue Hospital in New York City, brought on by a diet restricted by a man eating in public restaurants to pasteurized milk, cereal, and apple sauce. Sherman has expressed his belief, from personal observation in rural regions, that "much of the so-called rheumatism which afflicts such a large proportion of our people in winter and spring is due at least in large part to the use of diet too poor in vitamin C."[1]

Dr. E. Marion Delf, who has conducted extensive nutrition investigations in war-stricken Austria and in South Africa, calls attention to the effect which the long cooking of vegetables may have on a diet theoretically sufficient to maintain health if consumed raw

[1] Sherman, H. C. *Chemistry of Food and Nutrition,* 3d edition, page 438. The Macmillan Co. (1926).

or lightly cooked: "There is increasing reason to believe that, in institutions where the ration of anti-



(*Courtesy of Dr. A. F. Hess*)

Fig. 65.—Weight record of an infant given no antiscorbutic for five months, after which either boiled orange juice (O. J.) or orange peel extract (O. P. J.) obtained by boiling the white part of the rind in water, was added to the diet. Note that it took nearly five months for the scurvy to manifest itself as indicated by the decline in weight, but that growth was immediately resumed when an antiscorbutic was given.

scorbutic food is limited to cooked vegetables, a quantity which is theoretically about sufficient for the main-

tenance of health if consumed raw or lightly cooked, becomes quite inadequate after prolonged boiling, stewing or frying. For example, 82 men were affected with scurvy in a prison camp in Scotland in the spring of 1917. 'At the time potatoes were scarce, but the ration contained a fair proportion of fresh meat and 2 oz. of swedes were available daily. . . . The cause of the outbreak was investigated by Professor Hill, who discovered that the meat was always served as a stew, the vegetables were added, and the whole cooked for about five hours.' An outbreak of scurvy in a hospital in Vienna has recently been traced to the custom of twice cooking the vegetables provided, at a time when the daily allowance was necessarily somewhat limited. The evil effect on fresh food of prolonged heating or simmering has also been observed from time to time in certain South African mine compounds." [1]

Vitamin C may therefore be regarded as a dietary asset even to a species which shows no scorbutic symptoms, and one to be liberally used as a preventive of latent scurvy, a condition in which resistance to infectious disease is reduced; and to be regularly furnished to infants as a precaution against more or less retarded growth and interference with the normal development and calcification of the teeth.

[1] Delf, E. M. Studies in experimental scurvy, with special reference to the antiscorbutic properties of some South African foodstuffs. *South African Institute for Medical Research,* Publication No. XIV, Johannesburg, 1921.

SECTION 4

VITAMIN D

Prevention and Cure of Rickets

As in case of beriberi and scurvy, firm belief in a dietetic factor in rickets was held by many prior to the discovery of the B and C vitamins. A popular handbook of "information for everybody" bearing the date 1874, affords an interesting illustration of how experience may teach the right method of curing a disease before knowledge of the true cause of the disease makes it possible to explain why the cure is successful. Rickets is defined in this old book as "a disease almost peculiar to childhood, depending upon the want of a due proportion of the mineral salts in the blood, in consequence of which impoverished state the bones in a growing child are deprived of their proper amount of earthy ingredients, becoming consequently soft and pliable, instead of being naturally firm and resistant. . . . Defective assimilation of food is the professional term given as an explanation of the cause of this disease; the meaning of which is, that there is a deficiency of phosphate of lime, either in the food taken or in the system." This statement, written more than fifty years ago, does not appear strikingly different from the definition of 1923, formulated by Dr. Edwards A. Park, Professor of Pediatrics in the Yale School of Medicine, and one of the foremost of modern investigators in this field: "Rickets is a disturbance of the mineral factors in nutrition which results in a retarded

deposition of calcium phosphate in the developing bone." [1]

The method of treatment proposed half a century ago is not as different from to-day's as one might perhaps imagine from reading only recent literature on the subject. The old book says: "As the cause of this disease is an absence of the mineral salts, the natural remedy for the case would seem to be to give the system those salts of which it stands in need, namely, the phosphates of lime and soda. The cure, however, cannot always be effected by these means alone, though given in constantly repeated doses; the restoration to health can only be attained by a steady and gradual system of dietetics and regimen. The first indispensable requisite is change of air, and if possible, to the seaside; . . . and abundance of milk, and a full, rich diet—animal and vegetable—with fruit; the patient in this instance being enjoined to eat the rind or skin as well as the fruit, and when the digestion is good, water-cresses, radishes, salad, and any crude vegetable in which the mineral salts are in their natural abundance. . . . Though the diet and regimen are the chief agents required in the treatment of rickets, some medicine is necessary, and of that we shall now proceed to speak. In the first place, cod-liver oil, on account of the nitrogen or animalizing principle it contains, has been greatly recommended in this disease, and there can be no doubt that in cases of much debility it may be given with very great effect."

In this old household guide are the essentials of the

[1] Park, E. A. "The Etiology of Rickets," *Physiological Reviews*, Vol. 3, page 106 (1923).

treatment of rickets, as we understand the disease to-day: (1) the need of an adequate supply of calcium and phosphorus; (2) the value of ultra-violet radiation (going to the sunny seashore); and (3) the furnishing of liberal amounts of the antirachitic vitamin partly by means of fresh green food, but more effectively by giving cod-liver oil.

There was, however, no appreciation of the close connection between these different factors when the above was written. The first suggestion of a possible relationship between vitamins and rickets was made by Hopkins in 1906, in his introductory paper concerning "accessory factors in normal dietaries": "In diseases such as rickets, and particularly in scurvy, we have had for long years knowledge of a dietetic factor, but though we know how to benefit these conditions empirically, the real errors in the diet are to this day quite obscure. They are, however, certainly of the kind which comprises these minimal qualitative factors that I am considering." [1]

This marks the real beginning of the twenty years of experimental work which led to the discovery of the antirachitic vitamin and its occurrence in such high concentration in cod-liver oil; which explained how ultra-violet light could produce the same effect by acting on the cholesterol in the skin; and which showed that while strictly speaking the trouble is always with the mineral content of the blood there may be internal factors interfering with the utilization of a normal supply in the diet—sometimes excessive losses from

[1] Hopkins, F. G. "Analyst and the Medical Man." *Analyst*, Vol. 31, page 395 (1906).

the digestive tract, sometimes the rapid growth of muscles and other soft tissues, which, like bone, demand phosphorus—disturbances adjusted most readily by administration of the antirachitic vitamin of cod-liver oil or by treatment with direct sunlight [1] or ultra-violet radiation. Although the most noticeable symptoms of rickets are the changes in the bones, these are not in evidence until the disease is well advanced and are by no means the only part of the body affected. The vigorous attempts now being made to eradicate rickets are not made merely to save children from enlarged wrists and ankles or bowlegs—they are undertaken because the disease has been proven to menace the life and the health of children throughout the growing period.

Rachitic children are usually restless, irritable, and listless. The muscles are relaxed; on account of this, as well as the softening of the bones, walking is delayed; in the intestines there is sluggishness producing constipation, while the whole weak abdomen becomes distended in a pot belly. The ribs fail to develop properly, the breastbone is thrust forward, forming a pigeon breast, and the result is a contracted thorax which interferes with normal expansion of the lungs. Children who have severe rickets may carry their bony deformities throughout life. Some children also show severe anemia, and some a disturbance of the nervous system, resulting in convulsions. The condition of the greatest immediate significance, however, is lack of resistance to other diseases, especially those of the respiratory tract. Children with even mild

[1] Not through glass, which does not permit the passage of ultra-violet rays.

rickets suffer continually from colds and frequently succumb to bronchitis or pneumonia.

While rickets is more prevalent among artificially fed infants than breast-fed, the latter are by no means immune. Hess in 1922 estimated that in large cities like London and New York from 50 to 75 per cent of artificially fed children had rickets and that, although the breast-fed are far more immune, about 50 per cent showed signs of rickets by the end of March, the time when the disease reaches its peak. It is evident that for all babies some special factor of safety is necessary, wherever sunlight is not abundant throughout the year. Dr. Martha M. Eliot, Director of the Child Hygiene Division of the Children's Bureau and in charge of an extensive coöperative study of rickets in New Haven, Connecticut, under the joint auspices of the United States Children's Bureau and the Pediatric Department of the Yale School of Medicine, says from her experience in this study: "Preventive measures cannot be undertaken too early. It is during the first weeks of life that rickets develops in a large proportion of babies, and if the disease is to be controlled, sun baths as well as cod-liver oil must be given at this time. In the campaign for 'better babies' and healthier children, more stress must be laid on sunlight. . . . Many beneficial effects of sunlight are as yet unexplained but its power in the prevention and cure of rickets is proven." [1]

Attention should also be directed to the nutrition of the mother. The antirachitic vitamin can be

[1] Eliot, M. M. "Sunlight for Babies." *Child Health Bulletin*, Vol. 1, pages 35–38, June (1925).

stored in the body to an important extent. The influence of the diet of the mothers on the prevalence of rickets among their babies has been well shown by Hess, who in 1917 found in a negro community in New York City as high as 90 per cent of the whole number of infants rachitic. The mothers' diets proved on investigation to be almost totally lacking in the eggs, milk, butter, and green vegetables which would furnish considerable amounts of vitamin D. Systematic administration of cod-liver oil to 37 infants between four months and a year old for six months prevented rickets in all but three cases, while of 16 infants not receiving the oil all but one were affected.[1]

The Promotion of the Health and Growth of the Teeth

It has been estimated that the temporary teeth come through the gums practically perfect in 98 per cent of children. Nevertheless, according to Dr. H. D. Cross of the Forsyth Dental Infirmary,[2] 96 per cent of American children have defective teeth; and Dr. W. H. Leak, New York State Dental Inspector, said in 1920: "Ninety per cent of children in the first grades, not only in the slums but in aristocratic and best sections of cities, have bad teeth; one-third have abscessed conditions in their mouths, and every fourth or fifth child does not have proper masticating surfaces. Of little tots in the first grades, 7 years of age, 40 per cent have the six-year molar decayed—a tooth which has

[1] Hess, A. F., and Unger, L. J. "Prophylactic Therapy for Rickets in a Negro Community." *Journal of American Medical Association*, Vol. 69, page 1583 (1917). Also, "The Diet of the Negro Mother in New York City," loc. cit., Vol. 70, page 900 (1918).

[2] Cross, H. D. "Clean Teeth not Always Sound," *Nation's Health*, Vol. 5, page 609 (1923).

not been in the mouth more than one year and yet the first molar of the permanent set, decayed."[1] In 1914, when oral hygiene was introduced into the school system of Bridgeport, Connecticut, the average number of cavities in the teeth of children in the fifth grade was more than seven. A similar report from the Deaner Dental Institute of Kansas City, Missouri,[2] in 1922, states that, of 676 children between three and six years of age, 297 had carious teeth; and of 232 children from five to six years old, 145 or nearly two-thirds averaged over four decayed teeth per mouth. From this it was estimated that, of the approximately 8,000 children normally entering the first grade in this city each year, over 5,000 would need dental attention, and over 21,000 teeth would require surgical interference. Students of child welfare invariably include defective teeth among the common causes of undernutrition in children. There may be no striking symptoms, but there is liability to loss or perversion of appetite and disturbance of digestion and assimilation of food, to say nothing of the far more serious risk from tooth infection which may give rise to diseases of joints, kidneys, and heart.

Until very recently, measures for betterment of the very bad dental conditions found in American children have been chiefly directed to oral hygiene. But with the development of modern experimental methods in nutrition have come several striking demonstrations that the teeth, like the rest of the skeletal

[1] Cited by Snyder, J. R. "The Temporary Teeth." *Journal of the American Medical Association*, Vol. 75, page 458 (1920).

[2] Ripins, R. F. "The Incidence of Dental Caries and the Pre-school Age." *Journal of Dental Research*, Vol. 4, page 369 (1922).

structure, depend upon an adequate diet for their development and maintenance in health. The thought of a close connection between teeth and diet in case of human beings would have impressed itself sooner, perhaps, if the character of the teeth were not largely determined before birth and in infancy, before any teeth erupt and long before the permanent teeth appear. The calcification of the first set of teeth is said to begin between the fourth and the fifth months of pregnancy, and the calcification of the first permanent teeth (the 6-year molars) to be active in the last three months of prenatal life.

Food Factors Affecting the Teeth

The permanent teeth are rapidly forming during the period of lactation, and throughout all the years of growth calcification continues, at least up to the eighteenth year. Emphasis has already been placed on the need of an adequate supply of calcium for the mother during pregnancy and lactation, and for the growing child up to the twenty-fifth year; this must be reiterated in the present connection. Dr. Guttorm Toverud,[1] in a recent study of the influence of diet on teeth and bones, calls attention to the fact that the molar teeth of rats strongly resemble those of human beings, and shows that rats fed a diet low in calcium develop teeth low in total ash and in calcium, as one would expect. He also makes the interesting observation that the teeth are not as low in ash as one might imagine, but very brittle and have half again as much magnesium

[1] Toverud, Guttorm. "The Influence of Diet on Teeth and Bones." *Journal of Biological Chemistry*, Vol. 58, page 583 (1924).

as normal teeth, a partial compensation, apparently, for the absence of calcium.

The disastrous effect of scurvy upon the teeth has already been noted (page 265). To Howe's studies of the teeth of the guinea pig, Toverud adds observations on the degeneration of the pulp tissue, upon which the health of the tooth so greatly depends, beginning with hemorrhages in the upper part; and also analyses of some of the teeth, showing reduction in total ash and in calcium, with a much higher proportion of magnesium, as found in the rat experiment with low calcium.

Concrete evidence of the influence of vitamin A upon the teeth was first afforded by Dr. May Mellanby, who in 1918 fed two puppies a diet low in calcium and vitamin A, consisting chiefly of white bread with a little milk, linseed oil, yeast, and meat. They both had badly spaced teeth with poor enamel. A third, fed the same diet plus a little butter fat, was in much better condition as regards the placement and quality of the teeth. Further work showed that puppies fed during the period of development of the permanent teeth on diets deficient in vitamin A had thickened and poorly calcified jawbones and alveolar processes, irregularity in the arrangement of the teeth, delay in eruption of the permanent teeth, interference with the calcification of enamel and dentine, and abnormal development of the attaching tissues.[1] There appeared to be a direct relationship between the structure of the teeth and caries, those badly formed being more susceptible to disease. Diets low in calcium, vitamin A, and

[1] For an excellent summary of this work see McCollum, E. V., and Simmonds, N. *Newer Knowledge of Nutrition*, 3d edition, page 485 (1925).

vitamin C, singly or collectively, are undoubtedly unfavorable to the best tooth development. In addition, it is well known that babies with rickets exhibit delayed dentition and have teeth which are malformed, badly spaced, and subject to decay. It is at least highly suggestive that Cross finds that 96 per cent of children coming to this country from the southern part of Europe have sound teeth, while 96 per cent of American children have defective teeth; and even more significant that the foreigners' teeth begin to deteriorate after residence for some time in this country. It seems likely that the lessened amount of sunshine enjoyed in cities like New York and Boston, and the decrease in the amount of fresh green food may be large factors in this tooth deterioration.

That the form of rickets which results in nervous disturbance and convulsion in babies causes in later life enamel erosions of the permanent teeth has been noted by several eminent pediatricians. The teeth of rats on rickets-producing diets show decay resembling caries, and diseases of the sockets and attaching tissues. The strong belief in a connection between rickets and tooth defects is thus expressed by one of the best-informed and most conservative pediatricians: "Personally, I believe that if pregnant women received ample well-balanced diets, in which green vegetables were abundantly supplied and cow's milk was regularly taken, and they were kept a sufficient part of their time in the open air and sun, and their infants were placed in the direct rays of the sun for a part of each day and were fed cod-liver oil for the first two or three years of life, more could be accomplished in regard to the

eradication of caries of the teeth than in all other ways put together and that rickets would be abolished from the earth." [1]

It seems well to add that, although the period of the early development of the teeth is unquestionably of the greatest importance, the maintenance of healthy tissues of all kinds depends upon the continued consumption of a diet adequate in all respects, and that the teeth and their surrounding tissues are no exception to the rule. Whatever other causes of tooth disease there may be, we should at least be able in the next generation to rule out an inadequate diet, undoubtedly a factor of the greatest significance at all ages, but especially in the period of tooth development.

Section 5

VITAMIN E

The nutrition studies of the first quarter of the twentieth century have set a new standard in nutrition. They have brought the realization that the appearance or the feelings of a human being for a few weeks or months, or even a number of years of his life, are not a safe criterion as to the quality of his diet. They have also taught that a dietary which has proven inadequate for health and vigor in other mammals is not likely to be safe for man. And they have set as the final test of an adequate diet, one which is not only palatable, digestible, and able to sustain growth to the full adult size at the normal rate, but also one which makes possible reproduction and rearing of young at normal inter-

[1] Park, E. A. "Certain Factors Causing the Deposition of Lime Salts in Bone." *Dental Cosmos*, Vol. 65, page 176 (1923).

vals without undue cost to the mother; and defers the onset of senility, so that the period of vigorous middle life is lengthened both by early maturity and delayed old age. As Daniels says, "A diet which is in every way satisfactory will permit of early multiplication through an endless number of generations. In estimating the nutritive value of any food mixture assumed to be complete it would seem that the production of a fifth generation in as perfect a state of nutrition as that of the first, would be a fair criterion." [1]

Evans and Bishop have shown that this ideal cannot be realized without a specific fertility vitamin, no matter how good the dietary may be in all other respects. Without it there is in the male destruction of the germ cells. In the female, although ovary and ovulation are unimpaired, there is a failure of placental function with death and resorption of the developing young. If rats of proven fertility are placed on a diet lacking vitamin E, they will remain fertile for three or four months, thus showing that vitamin E can be stored in the body. Further evidence on this point has been obtained by feeding to a certain number of sterile females various tissues (liver, muscles, fat) derived from other sterile females, and to another group of sterile animals tissues from animals of proven fertility. In all instances the tissues of rats whose diet contained vitamin E provoked fertility, but in no case did the tissues of sterile rats cure sterility in another animal.

Vitamin E is transferred from mother to offspring during intrauterine life. This is proven by the fact

[1] Daniels, A. L., and Hutton, M. K. "Mineral Deficiencies of Milk as Shown by Growth and Fertility of White Rats." *Journal of Biological Chemistry*, Vol. 73, page 143 (1925).

that the tissues of newborn rats cure female dietary sterility.

From the oil of the wheat germ has been made an extract containing vitamin E, so potent that the daily administration of only three ten-thousandths of a gram (0.3 milligram) throughout the life of the male results in the maintenance of normal fertility. For a sterile female, the feeding or injection under the skin of five-thousandths of a gram (5 milligrams) at the inception of a new gestation insures a normal litter of vigorous young.

Section 6

SOURCES OF THE VITAMINS

It is impossible to contemplate the profound influence which vitamins exert upon health, growth, and even life itself, without at once being stimulated to inquire how we may be assured that these various regulatory substances are suitably provided in the daily diet. Although the technic of animal experimentation, which is so far the best means of studying the distribution of vitamins in food materials, is laborious and requires rigid scientific control, it is no more so than the technic for studying mineral elements occurring in minute quantities such as iron or iodine; and the study of the chemistry of the vitamins is fraught with no more difficulty than the study of enzymes or the potent secretions of glands such as the thyroid, parathyroid, or pituitary.[1]

[1] For a discussion of the chemistry of the vitamins, see Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition. The Macmillan Co. (1926); Sherman, H. C., and Smith, S. L. *The Vitamins*. The Chemical Catalog Co., Inc. (1922); Eddy, W. H. *The Vitamin Manual*. Williams and Wilkins Co. (1921).

For specific information regarding the occurrence of vitamins in food materials, recourse should be had to Table I of the Appendix embodying our present knowledge of their general distribution and to Chapter XI, in which the practical significance as sources of vitamins of some of our dietary staples will receive consideration. The following pages will be devoted to a brief discussion of the nature of these sources and some of the precautions which are necessary to conserve vitamins for human benefit.

Vitamin A

Vitamin A was first discovered in animal fats, butter, egg yolk, and cod-liver oil, and was not found in any of the oils of plant origin examined at that time. But very shortly it was found in the green leaves of alfalfa, cabbage, spinach, and young clover, and eventually Drummond showed that the cod and other fishes derive their vitamin A from small marine animals which in turn get it from various minute marine plants, algæ, and the like. Thus the dependence of the animal upon the plant for vitamin A was established. Furthermore, it was shown that when seeds are sprouted in the absence of light, little if any vitamin A is produced, but as soon as the sprouts come to the light and their tips begin to turn green, vitamin A is rapidly formed. Leaves which do not turn green, such as the inner leaves of lettuce and cabbage, are not nearly so rich in the vitamin as the green parts. In general, the thinner and greener a leaf is, the better source it is likely to be. Spinach stands unique in this class, being weight for weight in its fresh raw state more than the equivalent

of butter, or egg yolk. Next to green leaves, the growing stems or shoots of plants, and the germs of seeds are with few exceptions the most important vegetable sources. Green string beans are about as rich as the average head of lettuce.

The storage parts of plants, as thickened roots or tubers, and the endosperm of seeds, are relatively poor in vitamin A, but there is much variation among individual plants; yellow maize is richer than white corn; sweet potatoes, than white ones; and carrots are conspicuous among "underground" vegetables for a vitamin content higher than any other common vegetable except spinach. Of fruits investigated, the tomato is the richest; the banana is about as good as the average lettuce head; orange juice has about seven times as much as lemon juice, but only about one-eighth as much as tomato.

Animals may get their vitamin A from plants or from other animals. The grass-eating cow is a great conserver of this substance for human consumption. Milk stands preëminent among food materials as a source of vitamin A which is not all removed with the butter fat, skim milk containing an appreciable amount. The value of the milk and of the butter made from it is influenced by the diet of the cow, milk produced in the summer when the animal is furnished a plentiful supply of green food being richer than the winter product; but in practice this difference is much less than is generally supposed, because most milk comes from cows which get good hay or ensilage in winter.

The storage of A in the tissues of animals has already been referred to. Muscle contains very little under the

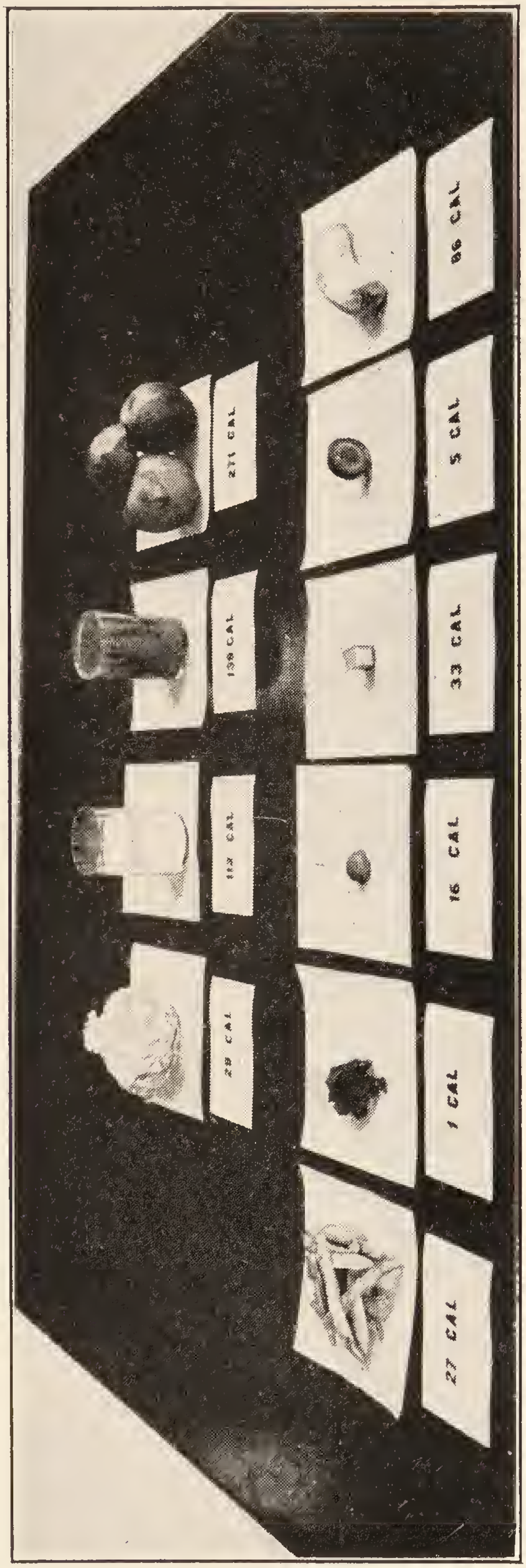


FIG. 66.—Amounts of Some Common Food Materials Required to Furnish the Same Amount of Vitamin A.

Food Material	*Grams*	*Calories*	*Food Material*	*Grams*	*Calories*
Lettuce	153	29	Spinach	4	1
Milk, whole	164	113	Egg yolk	5	16
Orange juice	323	139	Butter	4	33
Apples	430	271	Carrots	36	16
Beans, string	64	27	Bananas	87	86

most favorable feeding; glandular organs contain more, the liver being richest of all. Egg yolk resembles butter in its high content of A. Cod-liver oil has the highest concentration of any known source, being at least three times as rich as egg yolk. A cod-liver oil concentrate 2,000 times as rich as the original oil has been prepared in the laboratory. Fig. 65 from data collected by Munsell, shows the relative amounts of foods required to induce the same amount of growth in young rats in eight weeks.

Vitamin A in animal fats loses its potency gradually on exposure to the air, and more rapidly when thoroughly aërated, especially if the temperature is raised. As it exists in plant tissues it is not so easily oxidized and withstands drying and ordinary cooking temperatures without marked loss.

Vitamin B

Vitamin B is more widely distributed in nature than any of the other known vitamins, being found in both animal and plant tissues of many kinds. From rice bran the first antineuritic extract was made, but the rice embryo yields a greater amount. All of the cereal grains in their natural state are fairly rich in it, but polished rice and highly refined flours contain little, if any. Dried peas and beans and nuts seem to have much the same concentration as the cereal grains.

From yeast Funk obtained the antineuritic crystals to which he gave the name "beriberi vitamine," and yeast remains one of the most valuable laboratory sources. Brewer's yeast is more active than baker's,

but one gram of fresh compressed yeast daily furnishes adequate vitamin B for a growing rat.

A yeast concentrate at least ten times as powerful as the mother substance has been prepared in the laboratory and also a concentrate of the wheat germ; the later, however, is not so powerful as the yeast concentrate.

Leaves, stems, roots, tubers, and fruits are as a rule good sources. Little difference has been noted between potatoes, turnips, carrots, celery, and onions, but spinach is more than twice as rich as any of these, and cabbage at least twice as rich. On the whole, roots and tubers rank about the same among themselves and lower than leaves. Among fruits, the tomato is exceptionally rich; orange, lemon, and grapefruit juice are about equivalent to milk; grape juice, fresh apples, bananas, peaches, and pears have somewhat less.

In the egg, vitamin B is confined to the yolk, which weight for weight is three or four times as rich as the tomato, and at least five times as rich as milk.

Among animal tissues, skeletal muscles appear to contain much less than is found in heart muscle, liver, kidney, and brain. Sherman suggests that it may be because animals are receiving this vitamin so regularly in their food that they do not seem to have developed much capacity for storing it.

Just how much vitamin B will be present in foods when ready to eat depends upon how they have been treated. When wheat is made into fine white flour, the latter contains only one-tenth as much B as the original grain. When vegetables are cooked in water

and the juices thrown away, fully half the vitamin may be discarded in the cooking water.

Heating does not readily destroy this vitamin unless the temperature is raised above the boiling point; then destruction proceeds rapidly. The longer the heating continues, the greater the vitamin loss. The addition of soda greatly increases the rate of destruction and should be avoided in cooking fruits and vegetables. Those measures are best which accomplish the cooking most quickly and with least loss of the juices.

Drying does not seem to affect this vitamin unfavorably. Yeast, tomatoes, spinach, cabbage, turnips, carrots, and milk have all been dried without loss of vitamin B.[1]

Vitamin C

Vitamin C is produced by the plant in the process of its growth. It is not present in the dry mature seeds (at least of cereals and legumes), but develops as soon as they begin to sprout. It is found in all growing parts of plants, but is most abundant in actively functioning and succulent fresh green leaves, juicy stems, tubers, bulbs, roots, and fruits. Old-time remedies for scurvy, such as fir tops, pine needles, water and garden cresses, juices of scurvy grass, nettles, burdock, dandelions, field daisies, and turnips as well as of oranges and lemons, attest the wide range of vegetable sources discovered by man in the past. It

[1] For detailed information on the effect of canning on vitamins, consult Kohman, E. F. *Vitamins in Canned Foods*, National Canners Association, Research Laboratory, Bulletin No. 19-L, Revised (1924).

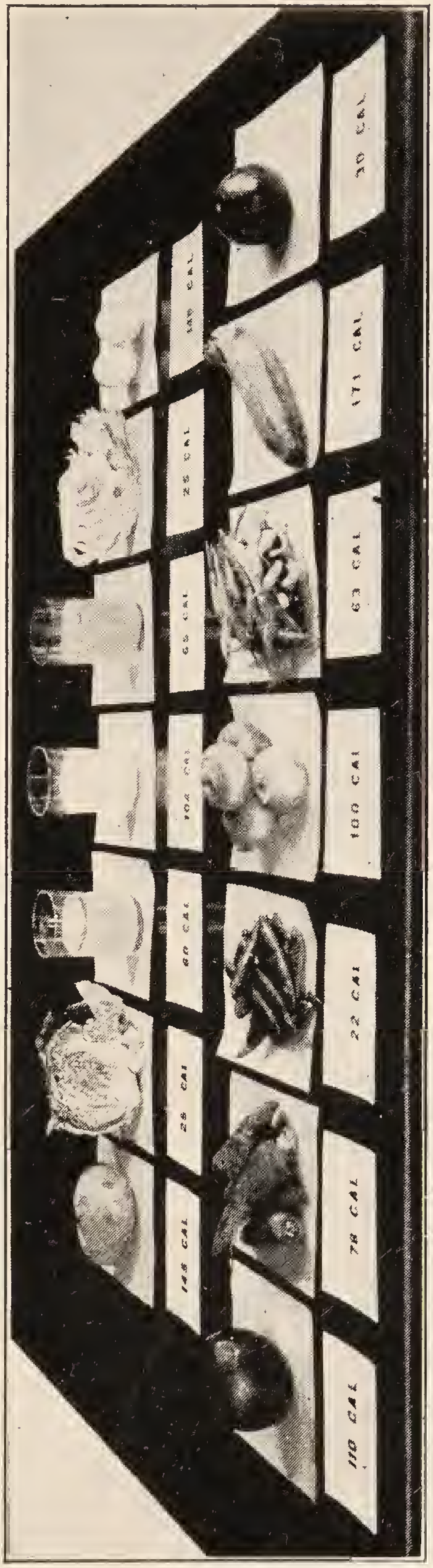


FIG. 67.—Amount of Some Common Food Materials Yielding Approximately the Same Amount of Vitamin B.

1st row, left to right	*Grams*[1]	*Calories*	*2d row, left to right*	*Grams*[1]	*Calories*
Potato	175	145	Apple	175	110
Lettuce	130	25	Carrots	175	78
Lemon juice	151	60	Peas	22	22
Milk	151	104	Onions	205	100
Orange juice	151	65	Beans, string	150	63
Cabbage	82	25	Banana	175	171
Eggs	100	148	Tomato	120	30

[1] *Weight of edible portion.*

must be noted, however, that many decoctions were boiled so long that it is probable that they owed their chief value to the orange or lemon juice which was frequently added. A preparation made by pounding oranges to a pulp, rind and all, unwittingly took advantage of the vitamin C in the rind as well as in the juice. Many were surprised to learn in 1918 that an extract of the white part of the rind was successfully used by Hess in his researches on the prevention of scurvy in infants. The signal difference between the period before the discovery of vitamin C and after is that now we know more precisely what we seek and how to conserve it. An old writer, who commends lemon juice as "a precious remedy and well tried," also suggests that when lemon or orange juice cannot be obtained "nitre dissolved in vinegar" or water acidulated with nitric acid may be substituted. To-day we know that it would be futile to place hope in the latter as a substitute for the former. We have substituted scientific knowledge for tradition.

As a general preventive of scurvy in the temperate zones the potato undoubtedly has held first place. Hess wrote in 1921; "It is hardly an exaggeration to state that in the temperate zones the development or non-development of scurvy depends largely on the potato crop. In Ireland, when the potato has failed, scurvy has developed. The same thing has been true in Norway. To a minor degree this happened in 1914 in various localities in the United States when the potato crop was inadequate. This is attributable in part to the fact that the potato is an excellent antiscorbutic, but to a greater extent because it is consumed during

the winter in amounts that exceed the combined total of all other vegetables." [1]

Scientific investigation has shown that vitamin C is very irregularly distributed in food materials and also very easily destroyed. It is necessary to know the conditions under which a food has been secured, the processes to which it has been subjected in preparation for the table, as well as its original store of the vitamin, to determine its practical value as an antiscorbutic. The fresh raw tomato, for instance, has not only a higher concentration of the vitamin than fresh raw potato, but is much less affected by cooking or drying. Fresh raw cabbage contains more vitamin C than fresh raw potato, but as Holst and Frölich discovered in their classic investigations of guinea-pig scurvy, it very rapidly loses its antiscorbutic value when heated, as shown by the larger quantities of cooked material required to protect the guinea pig; when dried at temperatures much below the boiling point, it loses the power to prevent or cure scurvy more or less completely, according to the length of time allowed for drying and the temperature maintained during the process.

Animal foods are less satisfactory sources of vitamin C than vegetable foods. Eggs have no antiscorbutic power and what little there may be in fresh raw muscle becomes practically negligible in meat as ordinarily eaten. Even in liver, which is normally well supplied with vitamins A and B, vitamin C is found in low concentration. The amount in fresh raw milk depends upon the diet of the cow; but in practice varies less with

[1] Hess, A. F. "Newer Aspects of Some Nutritional Disorders." *Journal of the American Medical Association*, Vol. 76, page 693 (1921).

the season than generally supposed, probably because of the present custom of feeding milch cows either ensilage or roots in winter. When the cow is in pasture eating fresh green grass there may be from three to five times as much as after months on dry feed. This makes it evident that a nursing mother cannot transmit to her offspring an ideal amount of this vitamin unless her own diet affords a liberal supply.

When milk is heated to destroy microörganisms the amount of vitamin C lost will depend upon the conditions under which the heating is conducted. Milk brought rapidly to the boiling point, held there two minutes, and quickly cooled loses less than that pasteurized for 20 minutes at 165° F. Milk dried rapidly at a moderate temperature seems to retain its antiscorbutic value. Since vitamin C is so important for the welfare of the infant, and since for sanitary reasons fresh raw milk in cities is seldom practicable for a large part of the population, it is best to give all artificially fed infants some food of high antiscorbutic value, such as orange or tomato juice, and to dismiss from further consideration the differences in antiscorbutic power of milk. It is also not disadvantageous to the breast-fed child six months or more of age to have a teaspoonful daily of orange or tomato juice and thus start the habit of taking some food specifically for its vitamin C value.

Heating, drying, and ageing have all been shown to be factors in the destruction of vitamin C, but operating differently with different foods, and demanding consideration of time, temperature, and other factors contributing to oxidation. Unless one has specific

knowledge (and generally for practical convenience) it is best to establish a habit of eating regularly some foods of undoubted antiscorbutic value, such as a wide range of fresh raw fruits and vegetables and canned tomatoes, in addition to potatoes.

For the full conservation of our food resources, it is necessary that a certain amount be canned or dried. Some kinds, as milk, orange juice, and lemon juice, have been commercially desiccated with little if any loss of antiscorbutic value; others, as most of our common dried fruits, cannot be counted as sources of vitamin C. From studies of canned peas, spinach, and cabbage made by Eddy and his associates it appears that vegetables are likely to lose less in commercial canning than in ordinary home cooking.

Cooking makes available many foods that otherwise would not be practical, and often enables us to eat larger quantities of vegetables than would otherwise be possible. For the conservation of vitamin C the cooking of vegetables should be done as quickly as possible, and the juices retained whenever feasible. It must be borne in mind that a relatively high loss in cooking may be only partly offset by the larger quantity eaten when the food material is cooked. As yet our knowledge of the exact quantity of vitamin C in different food materials is very crude, but Fig. 68 shows the relative amount in a few kinds which have been quantitatively investigated.

Vitamin D

The problem of dietary factors influencing the deposition of calcium in the body had received consider-

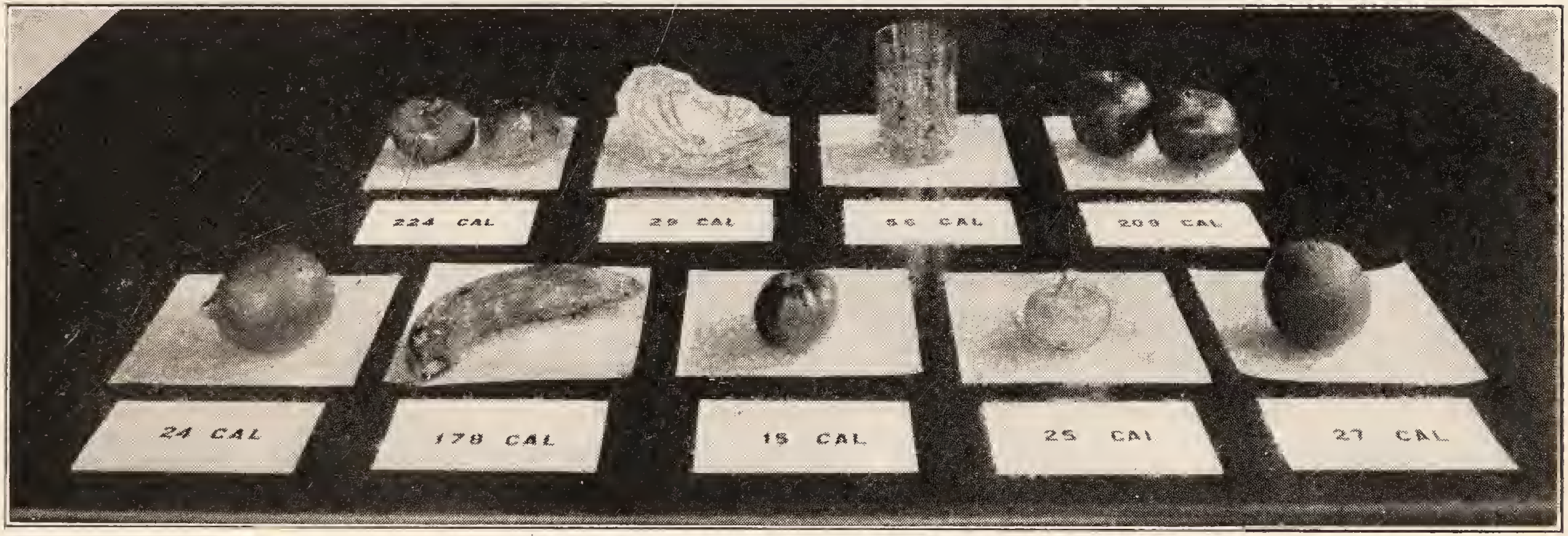


Fig. 68.—Amount of Some Common Food Materials Yielding Approximately the Same Amount of Vitamin C.

Food Material	*Grams* [1]	*Calories*	*Food Material*	*Grams* [1]	*Calories*
Potatoes, cooked	270	224	Banana	180	178
Cabbage, raw	90	29	Tomato	60	15
Peas, canned	120	56	Onion	50	25
Apples, raw	363	209	Orange (juice only)	60	27
Lemon (juice only)	60	24			

[1] *Weight of edible portion.*

ation from investigators of metabolism long before vitamin D was recognized as one of the specific agencies in this process. It was found that there was a marked difference in the ability of the animal to retain and utilize calcium when green grass, clover, or alfalfa was substituted for dry straw. Thus in 1913, Steenbock and Hart found that a goat reduced to the verge of physical collapse by failure to utilize the calcium furnished by a diet of oat straw, recovered with astonishing rapidity when fed oats and allowed to graze all day on June grass. The lime intake was the same as before but from the grass the calcium was retained instead of being excreted. The authors wrote: "This transformation is truly remarkable and from the standpoint of mineral metabolism stands unparalleled in the experimental field. From a nutritive condition which would ultimately have led to the occurrence of physical symptoms of osteomalacia there was brought about a complete restoration to the normal by a temporary change in ration. That the change of intake of lime was responsible for this transformation is out of the question, as the former ration, for maintenance, left little to be desired from the inorganic standpoint. Some subtle change in the trend of metabolism was instituted by the temporary variation in feed intake, as well as environment, which now enabled the animal to assimilate lime, formerly unavailable."[1]

To-day we are able to read this writing on the wall. The "subtle change in food intake as well as environment," we now interpret to be the ultra-violet rays of

[1] Steenbock, H., and Hart, E. B. "Influence of Function on Lime Requirement." *Journal of Biological Chemistry*, Vol. 14, page 71 (1913).

the sun to which the animal was exposed when put out to pasture, and the green food itself, which, as the same investigators showed later in a more detailed experiment,[1] increases the amount of calcium assimilated.

Compared with cod-liver oil and that of other fish-livers which have been found to be unparalleled sources of vitamin D, or to direct play of strong sunshine upon the body for some time each day, green leaves seem relatively insignificant, but that they are not negligible such experimental work as has been cited above fully attests. Comparatively little quantitative study of the antirachitic power of green vegetables has as yet been made, and there is doubtless a great deal of variability, depending on conditions of production and handling. Hence for babies and young children it is wise to supplement other sources of this vitamin with daily administration of from one to three teaspoonfuls of pure cod-liver oil, at least during the winter months, as well as to see that all (including adults) have daily exposure to the direct rays of the sun.

Milk resembles green foods in having a low concentration of vitamin D, but Sherman has cited large numbers of feeding experiments as evidence that milk, because it can be taken in considerable amounts, has important antirachitic value, although it should not be depended upon as the sole protective factor. Butter has a higher concentration than whole milk. In the experimental work which led McCollum and his co-workers to proclaim the existence of vitamin D as a

[1] Steenbock, H., Hart, E. B., and Hoppert, C. A. "Dietary Factors Influencing Calcium Assimilation. I. The Comparative Influence of Green and Dried Plant Tissue, Cabbage, Orange Juice, and Cod Liver Oil on Calcium Assimilation." *Journal of Biological Chemistry*, Vol. 48, page 33 (1921).

separate fat-soluble vitamin, they found both cod-liver oil and butter fat antirachitic, although much more of the latter than of the former was required to give complete protection.

Of all natural foods except fish oils, egg yolk seems to be highest in antirachitic value. Its possession of this valuable property was first demonstrated by Mellanby [1] who cured rickets in a dog by adding it to a rickets-producing diet. Since then it has been clearly demonstrated that egg yolk not only cures rickets in animals but that it can be employed for the prevention of this disease in infants. Thus Hess found that every one of twelve babies under one year of age given one egg yolk a day from December or January to March maintained a level of inorganic phosphorus in the blood characteristic of the summer months and showed no signs whatever of rickets; and Casparis, Shipley, and Kramer were able to demonstrate definite healing in seven colored children upon adding to a diet of cereal and milk one or two eggs daily. They comment on their work as follows: "It is interesting, in the light of these findings, to note that for centuries in rural England a food which must have had a very high antirachitic potency as well as a very high caloric value was universally eaten by children as well as adults. This food was known variously as 'furmity' or 'frumenty,' "an wholesome food," says Domini Holliday. The recipe for this food as given by Salmon was as follows: Take some new milk or cream and boil it with whole spice (nutmeg, cinnamon, clove). Then put

[1] Mellanby, E. "Experimental Rickets." *Medical Research Council of Great Britain*, Special Report, Series No. 61 (1921).

in your wheat or pearled barley boiled very tender in several waters; when it has boiled a while, thicken it with the yolks of eggs well beaten, sweeten it with sugar, and serve it in with fine sugar on the brims of the dish." [1]

Vitamin E

From the standpoint of practical nutrition, the important vitamins are A, B, and C, which so far as we know can be secured only from food, and whose functions in growth and in the maintenance of health at all ages have been proven beyond peradventure. While vitamin D is of unmistakable value as a constituent of the diet, the fact that the prevention of rickets can be brought about by ultra-violet light from the sun or a mercury vapor quartz lamp or by changes in the relative amounts of calcium and phosphorus, renders us less dependent upon food so far as D is concerned. There seems to be still less need of detailed knowledge as to the occurrence of vitamin E because of the low requirement for this substance and its very wide distribution in food materials.

According to Evans and his coworkers, vitamin E occurs in the greatest richness in the oil of the wheat germ, but is found in abundance in seeds and green leaves generally. In animal tissues it is present in low concentration, more being found in muscles and body fat than in the visceral organs. It occurs also in milk fat, but, as in case of the other vitamins, the amount present in milk is influenced by the character of the diet of the lactating animal.

[1] Casparis, Horton, Shipley, P. G., and Kramer, Benjamin. "The Antirachitic Influence of Egg Yolk." *Journal of the American Medical Association*, Vol. 81, page 819 (1923).

Vitamin E is not readily destroyed; on the contrary, its stability is remarkable. It is not affected by superheated steam, daylight, nor fairly strong acid and alkali, and consequently can be concentrated from such a source as wheat germ oil with comparative ease.

It is transferred from mother to offspring during intrauterine life, and can be stored for a relatively long time in the animal body. Practically, successful reproduction is less likely to be interfered with by shortage of vitamin E than by shortage of vitamin A; and the development of the nursing infant is more menaced by inadequate supplies of vitamins C and D than of vitamin E.

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CHAPTER XI

CONTRIBUTIONS TO THE DIET MADE BY VARIOUS TYPES OF FOOD MATERIALS

SECTION I

A METHOD OF STUDYING RELATIVE NUTRITIVE VALUES

In previous chapters we have considered the essentials of an adequate diet and have found that they may be stated under five headings:

(1) Energy to meet the daily expenditure; with surplus for storage only when actually needed for growth or to build up an underweight adult.

(2) Protein in sufficient quantity to replace daily nitrogen loss, and of such quality as to supply a liberal and complete assortment of indispensable amino acids, especially during growth.

(3) Ash constituents or mineral elements of many kinds, each with its own special function for which no other can be substituted, and all so related to the regulation of life processes as a whole that any failure of an adequate supply is likely to bring disaster, especially during growth.

(4) Vitamins, of which five are recognized (possibly others), serving as regulators of metabolism and controlling the processes involved in maintenance, growth, and reproduction.

(5) Water, not only an important constituent of the body, but the carrier of food to the tissues and waste away from them, and otherwise important in the regulation of body processes.

These dietary essentials may be conveniently summarized according to their main functions in the following way:

(1) Food as a source of energy or fuel for the body machine

Carbohydrates
Fats
Proteins

(2) Food as a source of material for the development and maintenance of body structure

Proteins
Ash Constituents
Water

(3) Food as a means of coördinating and otherwise regulating body processes

Ash Constituents
Vitamins
Water

What Relation Has a Food to the Diet?

Having learned what types of nutriment are needed to keep the body in prime working condition, our next task is to consider what relationship individual food materials have to the diet as a whole. Few foods consist, as does cane sugar, of a single chemical substance. The novice in nutrition is like a person who has never seen a watch: when he looks at it for the first time, all he observes is a shiny case with a glass front covering a dial bearing numbers from one to twelve, and

hands which revolve upon it. How different the mental picture of the watchmaker, who with his mind's eye looks through the metal case as if it were transparent and beholds delicate wheels, jewels, screws, and springs, all related to each other and harmoniously contributing to the beautifully coördinated movement of the whole! So it is with any article of food. To a person who has not studied nutrition, an orange is a bright-colored, fragrant globe inside of which are neatly packed sections yielding a delicious juicy pulp. It is just something good to eat. So are cake and pie and chocolate creams. But to the one who has learned to think in terms of nutritive value, an orange is a food shop. First, there is water—much of it; it constitutes nearly nine-tenths of the weight of the peeled fruit. Then there is sugar, amounting to one-tenth of the edible portion; a mere "sample" of protein; scarcely a trace of fat; varying amounts of a galaxy of mineral elements, including calcium, phosphorus, sulphur, iron, sodium, potassium, etc.; and lastly, vitamins A, B, and C.

Is an orange like a potato? Who would think so, to see or taste them? Yet they have much in common. The potato contains nearly as much water as the orange. It has starch where the orange has sugar, but these are both carbohydrates, serving interchangeably as body fuel. Protein is only slightly more plentiful in the potato, and fat is found as the same mere trace. The same mineral elements and vitamins may be found, though in different proportions.

If we set out to eat the same number of calories from oranges as from potatoes we may make some interest-

ing discoveries. Very likely we shall be able to eat day after day, without any digestive discomfort, more potatoes than oranges. The fact that oranges are acid and potatoes not may make some difference to our stomachs, but once safely through the digestive tract even the difference in acidity disappears, for the acid of the orange will be quickly burned away, and the two foods will be quite similar in their effect upon the blood.

In the course of such an adventure in eating, it may be borne in upon us that we do not relish the more pronounced acid-sweet flavor of orange along with all sorts of other foods. A plate of meat, orange and tomato may not seem quite as satisfactory as the more familiar meat, potato, and tomato. Again, if we live where oranges cannot be plucked off the trees, but have to be paid for at a rate to cover the vicissitudes of shipping long distances, we may find it a better policy to eat more potatoes than oranges, regardless of our personal preference.

Neither food will furnish adequate protein, so we shall not be safe in limiting ourselves to these two foods, no matter how much we like them. Moreover, the amounts necessary to furnish enough calories might prove something of a tax on appetite if not on digestion, as it would take in the neighborhood of three dozen medium oranges or two dozen medium potatoes for a rather sedentary man for a day; and then the oranges would not furnish enough iron nor the potatoes enough calcium nor either enough vitamin A! At last we should be driven to other foods for the compounding of a ration ideal in all respects.

Race Experience Does Not Insure Good Nutrition

Experience has taught the human race a great deal of practical value about diet but it is no guarantee of an ideal one. Some people with no scientific knowledge of nutrition are so situated as to be well nourished on their natural diet. McCarrison [1] cites certain isolated peoples in the Himalayas, whom he found remarkably vigorous, although living on what would seem to be a much restricted diet. "For nine years of my professional life," he says, "my duties lay in a remote part of the Himalayas, where there are located several isolated races, far removed from the refinement of civilization. Certain of these races are of magnificent physique, preserving until late in life the characters of youth; they are unusually fertile and long lived, and endowed with nervous systems of notable stability. Their longevity and fertility were, in the case of one of them, matters of such concern to the ruling chief that he took me to task for what he considered my ridiculous eagerness to prolong the lives of the ancients of his people, among whom were many of my patients. The operation for senile cataract appeared to him a waste of my economic opportunities, and he tentatively suggested instead the introduction of some form of lethal chamber designed to remove from his realms those, who by reason of their age and infirmity were no longer of use to the community." These people live on a very frugal diet, consisting of apricots which they sundry for winter use, vegetables and goat's milk; goats are the only live stock and while butter is made

[1] McCarrison, Robert. Faulty Food in Relation to Gastro-Intestinal Disorders. *Journal of the American Medical Association*, Vol. 78, page 1 (1922).

from the milk, goat's meat is eaten only on feast days.

Mellanby describes another isolated group on the Island of Lewis in the New Hebrides, whose houses are unsanitary, being windowless and full of smoke, and whose children get comparatively little sunlight; yet the death rate of their infants is very low and rickets practically unknown. Their diet consists mainly of milk, oatmeal, potatoes, turnips, and fish. A staple article of diet is cod's head stuffed with a mixture of oatmeal, milk, and cod livers, a diet which would seem very limited to an average American, yet has proven capable of a great saving of infant lives over that of English cities, where another type of limited diet appears, chiefly bread, jam, and tea. Here undernutrition and rickets and a high infant death rate bear testimony to the utter inadequacy of the diet. These contrasts make it evident that while here and there people may be so situated by nature that their diet happens to be adequate, others are far from attaining the vigor they might have if their foods were selected with more regard to their nutritive values.

While America is still the land of opportunity, and food is sufficiently plentiful and varied to prevent general outbreaks of deficiency diseases, we have in the last few years discovered that the nutritional state of our American school children is far from ideal; our draft records revealed a low state of vigor in case of many of our young men, and the increase of pellagra in our Southern states, a disease in which diet must be reckoned a significant factor, all bear witness to the need of intelligence in food consumption. It should

be a part of every child's education to learn what sort of contributions the different kinds of food material make to this composite thing which we call diet, and to understand that a diet is something to be built, like a house; that just as an architect might specify stone for foundations, tile and stucco for walls, wood for interior finish, glass for windows, slate for roof, wire for electric lighting, brass for door knobs, each in quantities to suit his plan, so we must each have a plan for our diet which shall free us from the dangers of "hit and miss" eating.

Nutritive Values Expressed as Shares of the Day's Requirement

We cannot discern these properties of food without the help of the chemist. Thanks to Atwater, we have extensive tables, giving the results of hundreds of thousands of analyses of food materials for protein, fat, carbohydrate, water, and ash (without regard to the various elements found in it).[1] Thanks to Sherman, we have tables embodying our best knowledge of the ash constituents,[2] and we also have some information as to the relative value of many foods as sources of the vitamins, as is indicated in Table I of the Appendix.

To the beginner these tables seem somewhat confusing from the multiplicity of figures embracing so many dietary factors, but it is possible for practical

[1] Atwater, W. O., and Byrant, A. P. *The Chemical Composition of American Food Materials.* U. S. Department of Agriculture Bulletin No. 28 (1899). Many of the data embodied in these tables have been put in form for quick reference in Rose's *Laboratory Handbook for Dietetics*, 2d edition (1921).

[2] Sherman, H. C. *Chemistry of Food and Nutrition.* Reprinted through the kindness of Professor H. C. Sherman in Rose's *Laboratory Handbook for Dietetics*, 2d edition (1921).

purposes to state the nutritive values of foods in quite a simple way.

The feasibility of thinking of the energy values of foods in terms of 100-calorie portions has already been stressed in Chapter II. Let us now think of a diet requiring 2,000 calories as made up of 20 such portions or a 3,000-calorie diet as consisting of 30 of them. It is customary, when desiring to represent the energy requirement of the average man by a single figure, to use 3,000 calories. Each 100 calories would then be $^1/_{30}$ of the day's requirement.

As we have already seen, the other requirements for the average man may be stated as follows:

Protein, 10 per cent of the total calories or 2.5 grams per 100 calories
Calcium, 0.67 gram or 0.023 gram per 100 calories
Phosphorus, 1.32 gram or 0.044 gram per 100 calories
Iron, 0.015 gram or 0.0005 gram per 100 calories
Vitamin requirements cannot yet be stated in quantitative terms, but there should be a liberal supply of foods known to be good sources of each.

In other words, we may say that each 100 calories should constitute a cross section of the day's ration and carry its own quota of each of the above mentioned substances. We may then call each $^1/_{30}$ of the day's requirement a "share."

one share of energy	=	100	calories
one share of protein	=	2.5	grams
one share of calcium	=	0.023	gram
one share of phosphorus	=	0.044	gram
one share of iron	=	0.0005	gram

If we put this in graphic form, allowing a certain length of line to represent one share, all the lines will be of equal length.

Let us now compare an orange and a potato on this basis. Enough edible orange to yield 100 calories

weighs 6.9 ounces and is furnished by one very large orange or two small ones; of edible potato it takes 4.2

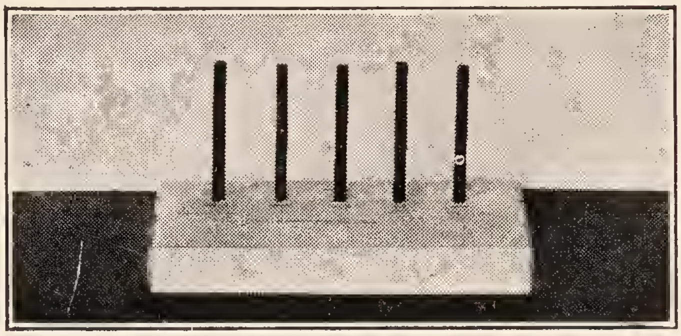


FIG. 69.—This block represents a cross-section of an adequate diet. Reading from left to right the pegs signify each one-thirtieth of an average man's daily requirement for energy, protein, calcium, phosphorus and iron and have the following values:

	Value of one "share"
Energy	100 calories
Protein	2.5 grams
Calcium	0.023 grams
Phosphorus	0.044 grams
Iron	0.0005 grams

ounces, equivalent to one potato of medium size. "Shares" of energy, protein, calcium, phosphorus and iron in a 100-calorie portion of each are shown in the following table.

SHARES IN 100-CALORIE PORTIONS OF ORANGE AND POTATO

	ORANGE "SHARES"	POTATO "SHARES"
Energy	1.0	1.0
Protein	0.6	1.1
Calcium	3.8	0.7
Phosphorus	0.9	1.6
Iron	0.8	3.1

Represented graphically and placed in juxtaposition to the "shares" in an adequate diet for an adult, the differences in the two foods and their relation to the diet as a whole are readily perceived. (Fig. 70.)

It is obvious that the orange has little more than half enough protein to be adequate by itself, whereas

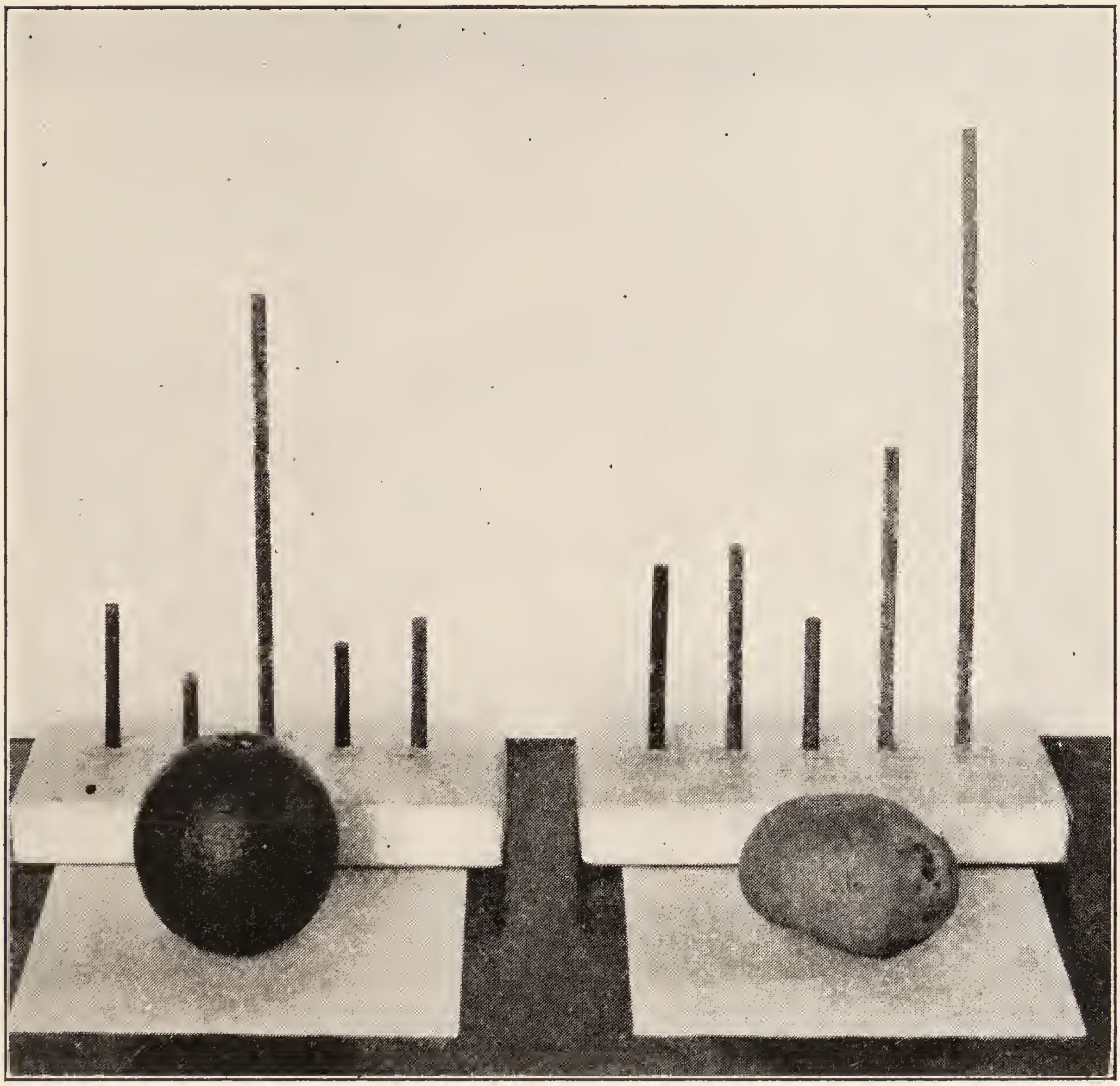


FIG. 70.—A comparison of the contributions to an adequate diet made by an orange and a potato. Reading in each case from left to right the shares contributed are as follows:

	ORANGE *Number of Shares*	POTATO *Number of Shares*
Calories	1.0	1.0
Protein	0.6	1.1
Calcium	3.8	0.7
Phosphorus	0.9	1.6
Iron	0.8	3.1

the potato can take care of itself very well, so far as quantity goes. As to quality it does not make such a

fine showing, because its protein, although capable of maintaining the adult in good health, will not support growth in the young, as shown by the following record of young rats whose sole source of protein was the potato. The quality of the protein of the orange has not been investigated.

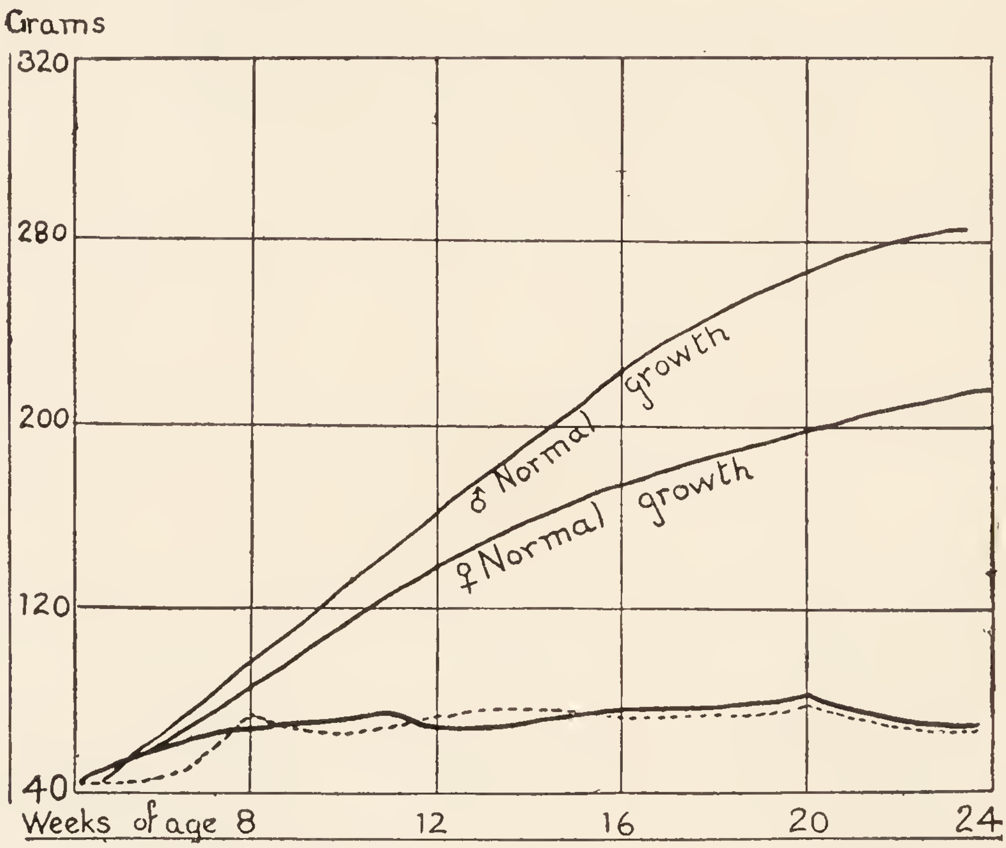


FIG. 71.—Growth of two young rats placed at the age of 4 weeks on a diet in which the protein was liberal in quantity but was derived entirely from the white potato. In 20 weeks they had attained no greater weight than they should have had at the age of 8 weeks.

It appears, also, that the deficiency of the potato in calcium is quite marked, and that a combination of half a share each of orange and potato would give us a mixture having calcium in excess of the dietary standard of one share per 100 calories, as it would yield an average of 2¼ shares of calcium. Similarly the deficiency of the orange in iron becomes apparent, and in strong contrast to the good supply in the potato;

a medium-sized potato can "take care of itself" so far as iron is concerned, and of at least three medium-sized oranges besides.

In all further discussions of the contributions which various types of food make to the diet, reference will be made to the "shares" of protein, calcium, phosphorus, and iron which they contribute, and in the Appendix tables giving the "share" values for many common food materials will be found.

As the general discussion of the vitamins in food materials has shown, there are as yet very few foods on whose vitamin content we may place a numerical value. It is convenient, therefore, to adopt symbols to express relative values. In comparing the orange and potato, the best we can do is to say that neither is a very rich source of A, both are fairly good sources of B, and both are excellent sources of C; all of which can be most succinctly expressed thus:

Vitamins in Orange and Potato

	Orange	Potato
Vitamin A	+	+
Vitamin B	++	++
Vitamin C	+++	+++

Foods Grouped According to Nutritive Value

It would be far beyond the scope of this book to discuss a large number of individual foods in the same detail as the orange and potato but, fortunately, many foods are quite similar in their chemical composition and nutritive properties and such we may group together, leaving for further study, with the help of the tables to which reference has already been made and

to books like Sherman's *Food Products*, the individual differences among members of the groups.

(1) **Milk** contains the greatest assortment of nutritive substances of all single food materials, and constitutes the foundation upon which an adequate diet can most safely and most easily be constructed.

(2) **The grains** give us primarily sources of energy, and secondarily of protein—not always adequate by itself, but when properly supplemented, of great practical value. Only by special selection does this class of foodstuffs become important for mineral constituents or vitamins.

(3) **Vegetables and fruits** are of greatest significance for their mineral constituents and vitamins. Only certain members of the group are good sources of calories, and still fewer of proteins.

(4) **Eggs, cheese, nuts, meat, fish, fowl, game, etc.,** are of prime significance for their yield of proteins of excellent quality. Eggs and cheese are also of the greatest value for certain mineral elements and vitamins. Whether or not meats make other valuable contributions to the diet depends upon the part of the animal which is represented.

(5) **Fats** are primarily sources of calories in concentrated form. In certain cases they are also carriers of the fat-soluble vitamins (A and D).

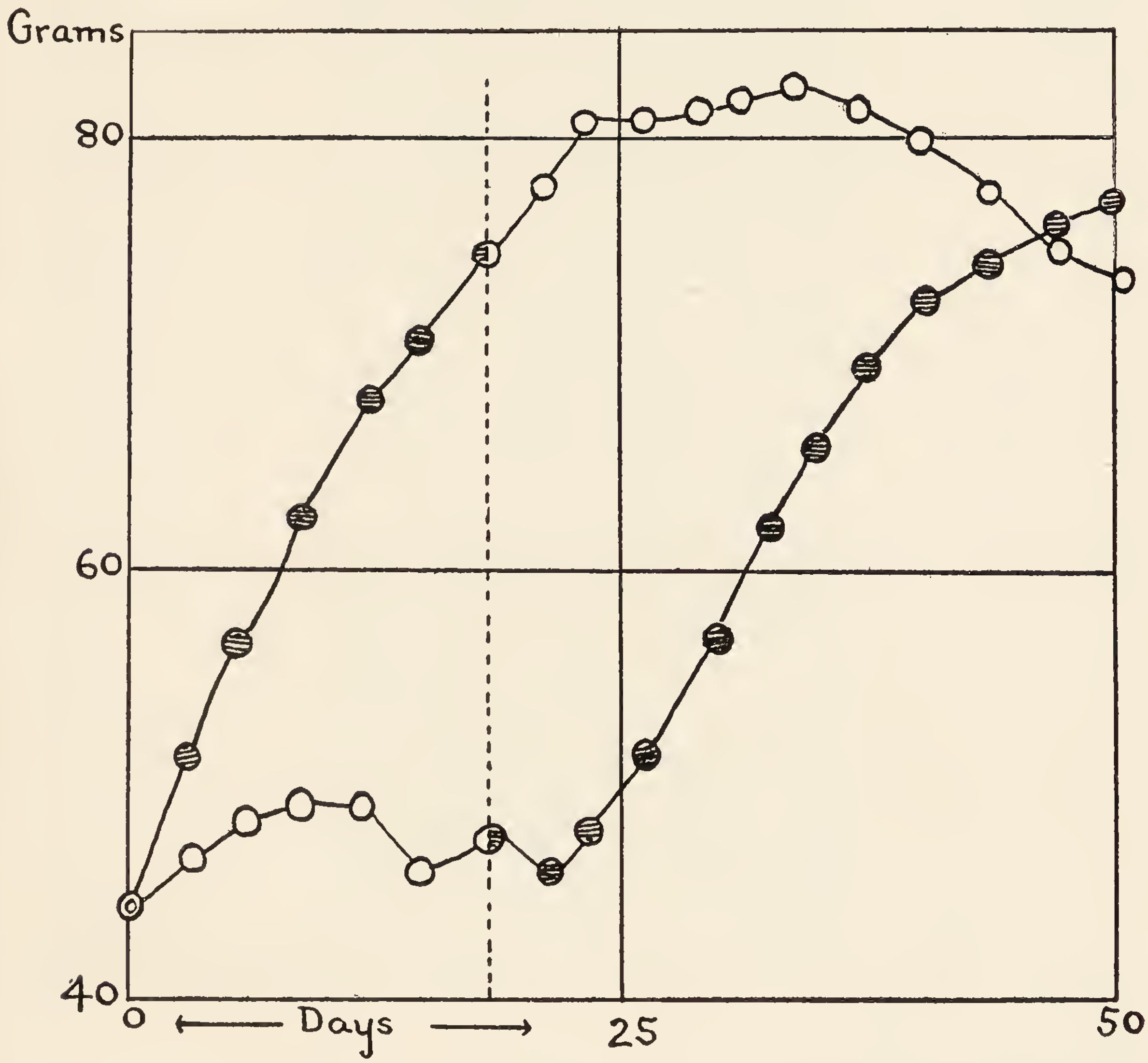
(6) **Sugars,** like fats, are sources of calories. Pure sugars contribute nothing else. A few foods containing sugar in high concentration make other contributions of some significance.

In the following pages the nutritive values of these various food groups will be discussed in more detail.

SECTION 2

MILK

In 1912 Hopkins published the now classic curves shown below, illustrating the effect on a rat's growth



(Courtesy of Dr. F. G. Hopkins)

FIG. 72.—The effect upon the growth of young rats of adding a small amount of a food containing vitamins to a diet of purified food materials.

The lower curve (up to the 18th day represented by the dotted line) shows the average weight of 8 rats upon the purified food. The upper curve, 8 similar rats taking 3 c.c. of milk daily. On the 18th day, the milk was transferred from one set to the other.

of adding to a ration compounded from purified food materials less than one-third of a teaspoonful of milk per day.

Other laboratory evidence of the high value of milk accumulated fast. Osborne and Mendel found that milk deprived of its protein and fat ("protein-free milk") enabled them to keep animals alive that otherwise would have died, and that milk protein (casein and lactalbumin) would promote growth when some other proteins would not. McCollum found a water-soluble growth-promoting substance left in the water from which milk sugar had crystallized out, and simultaneously with Osborne and Mendel discovered that milk fat had marked growth-promoting potency. A little later Sherman showed the difference in growth when varying proportions of milk were used in a diet of bread and milk; and again, the unique value of milk as a source of calcium for growing children which drew forth the following comment from the editor of the *Journal of the American Medical Association:* "The dietary rule of a quart of milk each day for every child is much more than a precept based on individual opinions or drawn by analogy from the results of feeding experiments with lower animals; it now rests on scientific evidence obtained by extensive and intensive experiments directly upon the children themselves."

These accumulating evidences of the many ways in which milk functions in nutrition have served to emphasize its indispensability, not only in the diet of the child, but also of the adult. No other food can so well serve as the foundation of an adequate diet, because no other reinforces it at so many points. It is for this reason that the term "protective food" is aptly applied to milk.

Energy Value

A quart of milk of average richness yields 675 calories. For the child a year old it will supply from two-thirds to

Fig. 73.—Contributions to the Diet made by a Glass of Milk Compared with a Standard Portion of an Adequate Diet.

	"Shares" in Standard Portion of Adequate Diet (*Left*)	*"Shares" in One Glass of Milk* (*Right*)
Calorie shares [1]	1.0	1.6
Protein shares	1.0	3.0
Calcium shares	1.0	12.1
Phosphorus shares	1.0	4.9
Iron shares	1.0	1.1

[1] Read shares from left to right.

three-fourths of the total calories required per day; for one five years old, about half the total calories; for a boy

or girl ten years old, about one-third; and for a city dwelling man of moderate activity about one-fourth. Drinking a single glass at each meal adds nearly 500 calories a day above what would be taken were water the only beverage. Thus it can be readily seen that milk, although nothing to chew, is not insignificant as body fuel.

By measure it takes five-eighths of a cup to make one "share" (100 calories). This is equivalent in energy value to an egg and a third or two yolks; to about two and one-fourth ounces of lean round of beef; to one medium potato or one shredded wheat biscuit.

For keeping the calorie intake of growing children up to requirement without disturbing appetite or digestion, milk's only rival is bread or other cereal food.

Protein

A quart of milk yields more than an ounce of pure protein of the highest quality, not only because of an assortment of essential amino acids whose efficiency in promoting growth is unexcelled, but also because under normal conditions it is the most completely digested and absorbed of all food proteins. From every point of view milk is an economical source of protein. It is produced at less expense than proteins of meat or eggs. An acre of cultivated farm land yields crops which when fed to farm animals give the following returns in human food: [1]

Food Produced	Protein, Pounds	Total Calories
Milk	289	711,750
Beef	74	130,000
Mutton	59	137,295
Poultry and eggs	110	148,675

[1] Sherman, H. C. "Place of Milk and Vegetables in the Diet." *American Medicine*, Vol. 13, page 361 (1918).

Milk enhances the nutritive value of bread and other cereal proteins, by adding those essential amino acids such as lysine and tryptophane in which cereal proteins are relatively poor. Experiments in feeding the lowest amount of protein capable of maintaining nitrogen balance in the adult have shown that less protein is required when milk is practically the sole source than when meat is so used and that proteins derived half from bread and half from milk furnish a mixture which is utilized with the same economy as milk alone.

A "calorie share" or 100-calorie portion of milk carries nearly two shares of protein, and milk is therefore to be regarded as relatively rich in protein, since only one share is necessary to "balance" the milk itself. The extra share is available to make good the lack in some other food. Thus 100 calories of butter plus 100 calories of milk, would give 200 calories with nearly two shares of protein, and therefore a mixture with a suitable relationship between total calories and protein calories.

Ash Constituents

In milk are found all the different kinds of mineral elements needed in nutrition. Milk ash strongly resembles in its composition the ash of the body of the newborn young to be nourished by it.

The table at top of page 318 gives the amount of the various mineral elements in one quart of cow's milk.

Milk is particularly adapted to offset the total lack of ash constituents in fats and sugars and the serious mineral deficiencies of white flour, hominy, polished rice and other refined cereal products so widely used in

Ash Constituents in One Quart of Cow's Milk

	Grams
Calcium	1.170
Magnesium	0.117
Potassium	1.394
Sodium	0.497
Phosphorus	0.907
Chlorine	1.034
Sulphur	0.332
Iron	0.002
Iodine	Present

American dietaries. Even where other sources of the mineral elements are included, such as fruits and vegetables, the need for milk remains, since the calcium of the diet depends more upon this than any other food. The contribution of a quart of milk in relation to the rest of a dietary which would be generally regarded as well selected is shown below:

A Day's Dietary Calculated in "Shares" to Show the Contributions made by Milk

	Calorie "Shares"	Protein "Shares"	Calcium "Shares"	Phosphorus "Shares"	Iron "Shares"
Bread, white	3.00	4.20	1.44	2.40	2.10
Butter	5.00	0.25	0.45	0.25	0.30
Potato	2.00	2.12	1.38	3.14	6.24
Egg	1.50	5.43	2.94	4.16	6.15
Apples	1.00	0.26	0.52	0.45	0.96
Oranges	1.00	0.62	3.83	0.91	0.78
Cabbage	0.50	1.02	3.11	1.05	3.49
Lettuce	0.10	0.25	0.97	0.51	0.75
Beef (lean)	2.50	13.64	0.92	8.30	7.70
Sugar	2.00	00	0.00	0.00	0.00
Oatmeal	1.00	1.68	0.74	2.25	1.92
Turnip	0.50	0.66	3.50	1.33	1.26
The above 12 foods	20.10	30.13	19.80	24.75	31.64
Milk, 1 quart	6.75	12.83	51.03	20.59	4.73
Total	26.85	42.96	70.83	45.34	36.37

In this dietary with two kinds of fruit, four kinds of vegetable, and one egg, milk contributes one-fourth of the calories, one-third of the protein, nearly three-fourths of the calcium, nearly half the phosphorus, and about one-eighth of the iron. What better evidence could one have of the way in which milk reinforces the dietary at many points?

The indispensability of milk as a source of calcium for the growing child has already been discussed at length and the desirability of a quart of milk daily to insure the best storage of calcium in the body has been emphasized. Sherman and Hawley found that about 70 per cent more calcium was stored with a quart of milk per day than with a pint and a half. To substitute vegetables for all of the milk would be practically impossible, even if their calcium could be as well utilized, since about four pounds of such as are relatively high in calcium would be required, and no child could eat so much in a day.

While phosphorus is less likely to be deficient in the dietary than calcium, since it is present in a wide variety of food materials, the necessity of a liberal supply makes the contribution of milk significant. When the calcium requirement is met through the use of milk, we have every reason to believe that the phosphorus requirement will also be covered.

Although milk is not as rich in iron as in calcium or phosphorus, the iron present is in a form which can be most completely absorbed and utilized, and in the diet of the young child a quart will furnish about one-fourth of the day's iron requirement.

Vitamins

"As cattle are furnished with a digestive apparatus permitting them to consume leaf foods in very large amounts, and have been bred to high efficiency in milk production, the milch-cow performs a most important service in bringing into form for human consumption large stores of vitamin A which have been formed in the green leaves of plants." [1]

A quart of milk yields nearly as much vitamin A as a pint of tomato juice or three quarts of orange juice or nearly two ounces of butter, carrots, or spinach. From laboratory experiences with diets in which milk furnishes one-fourth of the total calories, an amount corresponding to about a quart a day for each child and a pint for each adult in the average family dietary, it appears that the milk yields sufficient vitamin A for normal growth, and that additions from other foods, such as cream, butter, eggs, and green vegetables may therefore be regarded as an investment for periods of rapid growth in childhood or for special demands such as pregnancy and lactation in the adult, as well as the maintenance of a high resistance of the tissues at all times.

Milk is also rich in vitamin B, one quart being equivalent to a quart of orange or tomato juice, to one pound of spinach, or to two pounds of cabbage. Since the amount of vitamin B required increases with increasing size, and since the utilization of other foodstuffs has been shown to be promoted by liberal amounts of vitamin B, it seems fortunate that in taking milk for the sake of its protein, calcium, and vitamin A we

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 453. The Macmillan Co. (1926).

are also furnishing enough vitamin B to cover ordinary daily requirement and may regard that from other sources as so much extra health insurance.

Milk is less dependable as a source of vitamin C than of A or B. The amount in the fresh raw milk is not very large and is influenced by the diet of the cow and the heating which is in most places necessary as a sanitary precaution. According to Hess a pint per day of average fresh raw milk will protect a child from scurvy, but as this can be done equally well by a tablespoon of orange or tomato juice it is usually wise to use the safer heated milk and procure vitamin C from one of these foods or some other vegetable juice rich in vitamin C.

Milk contains some vitamin D and, having, besides, good proportions of calcium and phosphorus and a high content of both, is indispensable for the best bone growth, but should be reinforced by sunshine and egg yolk or cod-liver oil in order to insure full protection against rickets, as has already been pointed out in the discussion of vitamin D.

Summary

Milk owes its importance in the diet to the fine quality of its proteins and their supplementary value for the cereal proteins; to the completeness of its assortment of mineral elements and the excellent proportions in which they occur; to the high content of calcium, which makes milk almost indispensable for ideal storage of this element during growth; to the liberal amounts of vitamins A and B which make a quart of milk a day a practical guarantee against

deficiency of either; and to the presence of vitamin D in association with such a proportion of phosphorus to calcium as is most favorable to the calcification of bones and teeth.

This is the only material in nature designed solely to serve as food; and regularly used in liberal quantities, it is the best possible foundation for an adequate diet.

Section 3

THE FOODS DERIVED FROM GRAINS

Wherever we have agriculture, we have the cultivation of grain. This affords a staple article of diet which can be placed in reserve for seasons of scarcity, and one whose keeping qualities and ease of marketing make it relatively cheap. So it has come to pass that in many parts of the globe "bread" is the basis of the food supply. Dr. Vernon Kellogg, from his wide knowledge of food conditions in America and Europe during the World War, says: "Bread has not infrequently been referred to as the staff of life. But it really is. We of the Relief Commission found it so in feeding Belgium. The loudest call of the people, their principal anxiety and our first care all converged on wheat. The German experience as well as the Belgian one has shown that a dietetic régime for a semi-starving people is strong or weak, appeasing or dangerous, in proportion to the bread it contains." [1]

The proportion of the total calories obtained from bread in the United States and Great Britain bears witness to the importance of this item of the diet.

[1] Kellogg, Vernon, and Taylor, A. E. *The Food Problem*, page 5. The Macmillan Co. (1917).

Consumption of Bread in the United States and Great Britain

	Bread Given as Flour in gms. per Day	Per Cent of Total Cal. of Diet	Per Cent of Total Protein
United States	265	31	29
Great Britain	285	32	29
England	310	36	32

In most other European countries bread is still more prominent in the diet than in England. For half the people of the world rice is said to be the chief article of diet and corn is said to constitute one-third of the total intake of southern negroes. It is not conceivable that the cereals will ever be relegated to an unimportant place in the dietary. In fact, Dr. Alonzo E. Taylor of the Food Research Institute in California says: "In comparing the cereals with one another we are apt to emphasize their differences, just as we would in comparing two people. We do not remark that both have eyes; we say rather, one's are blue, another's brown; nor do we comment on both having vocal chords; we tell how one has a sweet voice while another's is gruff or strident. Any two men are more alike than a man and a dog, but we are so accustomed to the fact that it goes without saying. So we may first describe the dietary characteristics of the cereal family as we might describe the common traits of mankind as a class. Later we may consider them as individuals; looking at some of their peculiarities."

Seldom is the intact kernel of any grain used as food by man in any considerable amount. It is not easy to eat dry whole grains. From time immemorial they have been ground, crushed or otherwise treated, to break up

or remove the bran coats. In more recent times, with the increase of trade and the shipping and storing of grain foods, the germ has been removed because it is here that insects love to deposit their eggs, and the result is ruin so far as fitness for human food is concerned. Also the oil of the germ tends to become rancid and spoil the flavor. Hence the germ or embryo is removed and used for the feeding of animals or other purposes.

By ordinary cereal foods, then, we mean, unless there is a distinct statement to the contrary, degerminated and not whole grain. Very frequently cereals containing bran are called "whole grain" cereals, when they merely contain more or less bran but not the germ. In case of oatmeal, the greater part of the germ and a considerable part of the bran are to be found in the milled product. White rice (polished) has lost both germ and bran, while brown rice (cured) is free from the husk but retains most of the bran and germ. Pearl barley and barley flour are devoid of both bran and germ. "New Process" cornmeal has no germ and little bran. Entire wheat flour has part of the bran removed, graham flour, shredded, puffed, and rolled wheat are practically whole grain, while white flour has neither bran nor germ.

Since we have a rich source of calcium in milk, and relatively more in many vegetables than in any cereal food, there is little occasion to select cereals with reference to their calcium content unless very much limited in the milk supply. If such an unfortunate situation should arise, it would become important to choose with a view to getting as much calcium as

possible, in which case emphasis should be placed upon oatmeal.

FIG. 74.—"Shares" Contributed to the Diet by Individual Portions of Shredded Wheat, Rolled Oats, Dark Farina and Rice. Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a child (right).

	Standard Portion of Adequate Diet For Adult	*Shredded Wheat* (1 Biscuit)	*Rolled Oats* (1 cup, cooked)	*Dark Farina* (¾ cup, cooked)	*Rice Polished* (¾ cup, cooked)	*Standard Portion of Adequate Diet For Child*
Calories [1]	1.0	1.0	1.0	1.0	1.0	1.0
Protein	1.0	1.4	1.7	1.4	0.9	1.0
Calcium	1.0	0.5	0.7	0.5	—	1.5
Phosphorus	1.0	2.0	2.3	2.0	0.6	1.3
Iron	1.0	2.5	1.9	2.5	0.5	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B, and C

	Shredded Wheat	*Rolled Oats*	*Dark Farina*	*Rice* (Polished)
Vitamin A	+	—	+	—
Vitamin B	++	++	++	—
Vitamin C	—	—	—	—

Energy Value

Since the uncooked cereal foods are all very low in moisture content, and have great similarity in chemical composition, they have much the same energy value, approximating 1,650 calories per pound. The weight of a 100-calorie portion (dry) is close to one ounce, although the space occupied by one ounce will differ

with the coarseness of the material, from three tablespoonfuls of patent wheat flour to 1¼ cups of puffed wheat, or one shredded wheat biscuit. When cooked, there will be variation in weight as well as measure, due to the amount of water absorbed. Thus three tablespoonfuls of grapenuts are equivalent in calories to a cup of cooked oatmeal mush.

Protein

From 8 to 12 per cent of the calories in cereal foods are derived from protein. In their analysis of 224 American dietaries Sherman and Gillett found that grain products contributed 38 per cent of the total calories and 37 per cent of the protein, and in a series of studies made at the University of Maine grain products furnished 40 per cent of the fuel value and 25 per cent of the protein. It is generally safe to assume that in grain products about one "share" of protein will accompany a "share" of energy.

We have already seen, in the discussion of protein in Chapter VII, that individual cereal proteins differ in their amino acid assortment, but that several kinds of protein are found in one grain, and the proteins of bran and germ tend to supplement those of the endosperm. Laboratory experimentation has shown that the proteins of wheat, oats, maize, rye, and barley are about equally efficient in promoting and supporting growth. None of them is quite equal in value to an equivalent weight of the complete proteins which we find in milk, eggs, or meat, but all of them can be made highly efficient by combination with relatively small amounts of milk.

The proteins of wheat flour will not support growth as well as those of the whole grain, although very efficiently used in the maintenance of the adult. But if bread be made with milk instead of water, or if breakfast cereals be eaten with milk, the value of the combination may equal the average protein value of an ordinary mixed diet.

The Ash Constituents

While there is much similarity in the energy and protein values of cereal foods, including highly refined flour and white bread, there is great diversity in their yield of ash constituents. Much of this is due to milling, since the outer coats of the grains contain most of the mineral matter. The cereal foods, even when made from the whole grain, are deficient in calcium as the following table shows:

"Shares" of Calcium in 100-Calorie Portions of Common Cereal Foods

Buckwheat flour	0.48
Cornmeal	0.22
Entire wheat grain	0.56
Hominy	0.09
Macaroni	0.26
Oatmeal	0.74
Rice (brown)	0.14
Rice (polished)	0.05
Rye flour	0.22
Shredded wheat	0.48
White bread (water)	0.20
White flour	0.26
Whole wheat bread (water)	0.33

The whole grains carry more than their own quota of phosphorus, but this, again, may be much reduced by milling. It will be noted that even when milk is used in making wheat bread, only that made with

whole wheat does not need supplementing for phosphorus.

"SHARES" OF PHOSPHORUS IN 100-CALORIE PORTIONS OF COMMON CEREAL FOODS

Buckwheat flour	1.48
Cornmeal	1.20
Entire wheat grain	2.68
Hominy	0.61
Macaroni	0.91
Oatmeal	2.25
Rice (brown)	1.36
Rice (polished)	0.61
Rye flour	1.86
Shredded wheat	2.02
White bread (milk)	0.73
White bread (water)	0.53
White flour	0.59
Whole wheat bread (milk)	1.53
Whole wheat bread (water)	1.33

Of the mineral elements lost in the manufacture of white flour, iron is the one that can be least well spared. In 92 dietaries analyzed by Sherman cereals contributed one-fourth of the total iron. Since the less the money available for food the more dependence there will be on the cereal foods, those yielding iron should be regularly chosen, as they can be made the carriers of this essential element with little or no extra cost. From studies of children's dietaries which have been made under the writer's supervision, it seems quite evident that no very economical diet for a child can be liberally supplied with iron without the use of cereal foods (including breadstuffs) which contain it. With regard to the utilization of the mineral constituents of the wheat grain, Sherman makes this significant statement: "Three-fourths of the ash constituents of the wheat kernel are lost to man in the process of manu-

facturing the wheat into white flour. Doubtless the loss in digestion is somewhat greater for the coarser than for the finer products in the case of the ash constituents as of the proteins, but there is no reason to suppose that the loss in digestion would in any case approach the loss involved in the ordinary milling process. The body probably absorbs from a pound of genuine whole wheat bread at least twice as much phosphorus, iron, and calcium compounds as from a pound of white bread." [1] The recent suggestion of Simmonds, Becker, and McCollum[2] that iron is better utilized when vitamin E is present in liberal amount will, if substantiated, lend further emphasis to the advantage of cereal preparations from the whole grain as sources of iron.

The high iron yield of oatmeal and of wheat preparations including bran is clearly shown in the following table:

"Shares" of Iron in 100-Calorie Portions of Common Cereal Foods

Buckwheat flour	0.68
Cornmeal	0.60
Entire wheat grain	2.80
Hominy	0.50
Macaroni	0.66
Oatmeal	1.92
Rice (brown)	1.16
Rice (polished)	0.52
Rye flour	0.74
Shredded wheat	2.46
White bread (milk)	0.50
White bread (water)	0.53
White flour	0.46
Whole wheat bread (milk)	1.20
Whole wheat bread (water)	1.20

[1] Sherman, H. C. *Food Products*, revised edition, page 334. The Macmillan Co. (1924).

[2] Simmonds, Nina, Becker, J. E., and McCollum, E. V. "The Relation of Vitamin E to Iron Assimilation." *Journal of the American Medical Association*, Vol. 88, page 1047 (1927).

A B C D E

FIG. 75.—"Shares" Contributed to the Diet by Amounts of Bread Easily Eaten at a Meal Compared with a Standard Portion of an Adequate Diet.

	A *Standard Portion of Adequate Diet*	B *White Bread made with Water* (59 grams)	C *White Bread made with Milk* (49 grams)	D *Whole Wheat Bread made with Water* (61 grams)	E *Whole Wheat Bread made with Milk* (52 grams)
Calories[1]	1.0	1.5	1.5	1.5	1.5
Protein	1.0	2.3	2.1	2.3	2.3
Calcium	1.0	0.3	1.3	0.5	1.7
Phosphorus	1.0	0.8	1.1	2.0	2.3
Iron	1.0	0.8	0.8	1.8	1.8

[1] Read shares from left to right.

Relative amounts of Vitamins A, B, and C

	Bread B	Bread C	Bread D	Bread E
Vitamin A	—	+	—	+
Vitamin B	+	++	++	+++
Vitamin C	—	—	—	—

Vitamins

Whole grains, like other seeds, are relatively poor in vitamin A, and whatever amount is present is found chiefly in the germ so commonly removed. Hence no dependence should be placed on cereals for this vitamin.

On the other hand, the cereal grains contain liberal amounts of vitamin B, being from four to seven times as rich in it as the diet as a whole probably needs to be. Here again, the embryo and bran are the more abundantly supplied parts, the endosperm having little or none.

The cereal grains, like other dry seeds, do not contain vitamins C or D, but the germ and the oil expressed from it are rich in vitamin E.

Summary

The cereal foods as a class are primarily sources of energy, valuable for their abundance, economy, ease of digestion, and bland flavor. Since they can be eaten freely by all, they become significant as sources of protein although it is not of such quality or quantity as to permit of their being relied upon as the sole source. When those preparations are selected which include the bran and possibly the germ, the cereal foods, including bread, may make important contributions to the mineral content of the diet (especially iron) and also to the vitamin B content.

Section 4

VEGETABLES AND FRUITS

Advances in the science of nutrition have brought into prominence foods which formerly were held in too low esteem. As long as knowledge of nutritive values of food was limited principally to proteins, fats and carbohydrates, foods which were not good sources of one or all of these received scant consideration. Such energy-bearing vegetable foods as dried seeds of legumes, potatoes, and bananas might be assigned a definite place in the diet, but anything as watery as a tomato seemed a misguided choice to one whose main thought was calories, since for the same money twenty times as many might be purchased in the form of oatmeal or

other cereal food. But research was steadily progressing in regard to phases of nutrition other than calories and protein, as has been shown in the chapters on ash constituents and vitamins. In 1907 Sherman's bulletin, *Iron in Food and its Functions in Nutrition*, was issued by the United States Department of Agriculture, bringing together for the first time in an American publication evidence that food iron, existing as complicated organic compounds built up by the life processes of the plant, is the kind of iron needed by the body for making hemoglobin. A little later (1911) the same author published the first edition of the *Chemistry of Food and Nutrition*, and gave to students of nutrition quantitative dietary standards for iron, calcium, and phosphorus, along with the first reliable tables of data on the mineral elements in common food materials. Later work has only served to emphasize the importance of even a mere trace in the body of some essential mineral element, and the great value of vegetable foods especially when the amount of milk consumed is below the optimum.

This was also the period of discovery of the vitamins and search for them in food materials. In 1912, Holst and Frölich reported the finding of an antiscorbutic substance in a number of vegetables, including cabbage, carrots, cauliflower, lettuce, dandelions, and endive, and also in a variety of fruits. In 1916, vitamin A was found in cabbage, in 1918 in carrots, in 1919 in green peas, spinach, and sweet potato, in 1920 in chard, orange juice, and tomato. Vitamin B was found first in beans in 1901, in white potatoes in 1906, and in peas in 1907. In 1916 it was reported in cabbage, in 1918 in carrots, in 1919 in beets (root, stem, and leaves),

onions, spinach, turnip, and tomato, in 1920 in apples, celery, cucumber, radishes, lemon and orange juice, pears and prunes. By this time its wide distribution among vegetables and fruits was clearly demonstrated. To-day we know that a tablespoonful of tomato juice will yield as much vitamin A as a teaspoonful of butter, as much vitamin B as a tablespoonful of milk, and as much vitamin C as an equal measure of orange or lemon juice. We also know that spinach has weight for weight as much vitamin A as butter or egg yolk, twice as much vitamin B as tomatoes, and so much vitamin C that even when cooked it is equal to many raw vegetables. We can now read new meaning into old statements as to the value of vegetables in the diet—a value attested by experience, although then scientifically unexplained. In 1901, Mrs. Ellen H. Richards, pioneer in practical dietetics and strict economist, wrote in *The Cost of Food:* "Asparagus, lettuce, celery, etc., owe their popularity and efficiency not to their food values reckoned in calories or proteids but to the stimulus to the nerves given by the very small quantity of sapid principles. Used with discretion, these are adjuncts worth the excessive price. For a pound of food value in this form $1.00 to $2.00 is often paid instead of 1 to 2 cents for a pound of wheat or corn. The cost of many of these things is now excessive because their real value is not appreciated, and efforts are not directed to producing and preparing them." [1]

Not only because of their valuable ash constituents and vitamins, important as we now concede these to be, do vegetables and fruits deserve a place in the diet.

[1] Richards, E. H. *The Cost of Food*, pages 30–31. John Wiley & Sons (1901).

Many of them have laxative properties which amply justify their use. The human intestinal tract is so constructed that a certain amount of ballast or roughage is needed to keep the muscles in condition and insure prompt elimination of waste. The fibrous framework of leaves, stems, and even some bulbs, tubers, and roots, yields a spongy mass which serves the purpose admirably. Furthermore, the mineral salts and the mildly acid juices found in many members of the group give additional stimulus to intestinal activity.

Energy Value

Vegetables and fruits vary so greatly in their energy value that no general statement is applicable to all. Reference must be made to tables giving weight or measure[1] for satisfactory information about individual members of this group. Vegetables may be any part of a plant—leaf, stem, bulb, tuber, root, seed or seed pod, blossom or fruit—and like parts tend to similarity in composition. Acid fruits, flowers, leaves, and stems, such as tomato, cauliflower, lettuce, cabbage, asparagus, and celery, are practically negligible so far as calories are concerned. Fleshy roots, bulbs, and tubers, being storage parts of the plant, contain energy-yielding carbohydrates either as starch, as in the white potato; or sugar, as in the carrot; or both, as in the sweet potato. From five to ten ounces of any such vegetable will yield one hundred calories. Seeds are higher in energy value than other storage parts, and when mature and dry resemble the cereal foods, having a fuel value of about 100 calories per ounce.

[1] Rose, M. S. *Laboratory Handbook for Dietetics*, 2d edition. The Macmillan Co. (1921) and *Feeding the Family*, 2d edition. The Macmillan Co. (1924).

Among fresh fruits there is also much variability, but many common ones resemble the underground vegetables. It takes almost the same weight of banana as of white potato to yield 100 calories; about the same of apple as of onion; nearly the same of peaches as of carrots; and the same of cranberries as of beets. Some of these relationships are shown in the following table:

A Comparison of Energy "Shares" (100 Calories) Per Pound of Edible Material in Some Fresh Fruits and Vegetables with those in Cereals and Dried Sweet Fruits

Cereals, Dried and Fat Fruits "Shares"		Sweet Fruits and Vegetables "Shares"		Fruits and Vegetables with little Sugar or Starch "Shares"	
Rice	15.91	Pineapple	1.96	Celery	0.84
Cornmeal	16.13	Carrots	2.05	Lettuce	0.87
Wheat, flaked	16.48	Beets	2.09	Asparagus	1.01
Dried Sweet Fruits		Onions	2.20	Tomatoes	1.03
Prunes	13.68	Oranges	2.33	Rhubarb	1.05
Figs	14.37	Apples	2.85	Spinach	1.08
Raisins	15.63	Pears	2.87	Kohl-rabi	1.40
Dates	15.75	Grapes	4.37	Turnips	1.79
Fat Fruits		Bananas	4.47	Lemons	2.01
Avocado	13.57	Peas, green	4.54	Cranberries	2.11
Olives	13.57	Corn, green	4.59	Currants	2.59

With the exception of dried fruits and legumes, which per pound yield nearly as many calories as the cereals, we must regard our common fruits and vegetables as contributing only moderately to the energy value of the diet, although when used freely as is the case with potato they may have more significance as sources of calories.

Protein

Fresh vegetables and fruits are not large contributors to the total protein of the diet. Fruits seldom carry more than half enough protein to balance their own

calories; root vegetables usually yield a protein "share" for every calorie "share," but have little surplus to make good the protein deficiencies in other foods. In this respect they resemble the cereals. Green vege-

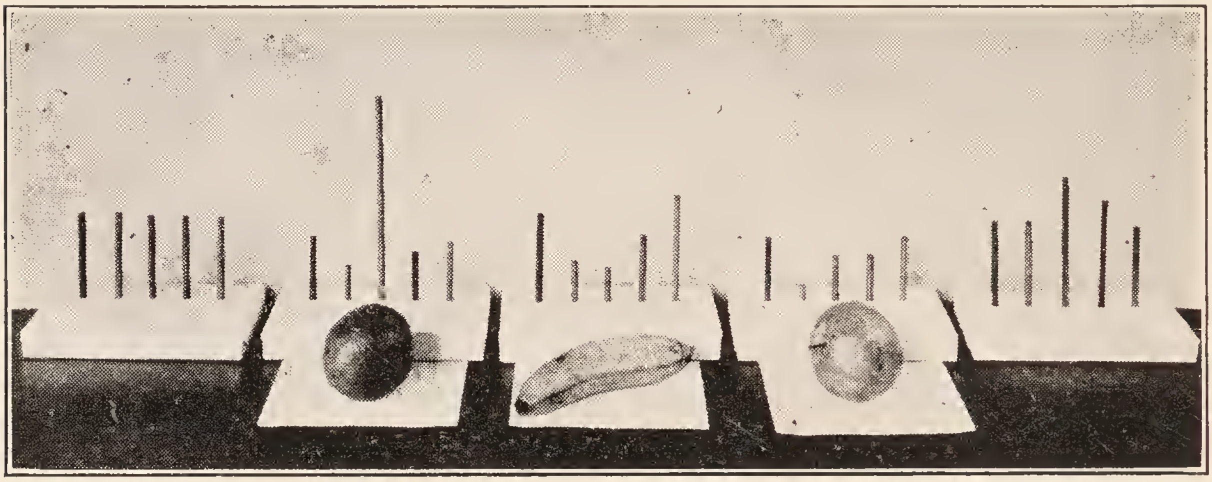


FIG. 76.—"Shares" Contributed to the Diet by an Orange, a Banana and an Apple. Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a Child (right).

	Standard Portion of Adequate Diet for Adult	*Orange* (1 medium)	*Banana* (1 medium)	*Apple* (1 medium)	*Standard Portion of Adequate Diet for Child*
Calories [1]	1.0	0.8	1.0	0.8	1.0
Protein	1.0	0.5	0.5	0.2	1.0
Calcium	1.0	3.1	0.4	0.4	1.5
Phosphorus	1.0	0.9	0.7	0.4	1.3
Iron	1.0	0.7	1.2	0.8	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B, and C

	Orange	*Banana*	*Apple*
Vitamin A	+	+	+
Vitamin B	++	+	+
Vitamin C	+++	++	++

tables are in proportion to their calories surprisingly rich in protein, a 100-calorie portion of chard or spinach yielding as many protein "shares" as one of eggs or buttermilk; and a 100-calorie portion of peas as much protein as one of cheese. But in consequence of the fact that one would be likely to eat four or five times as many calories of cheese or

egg as of spinach, the total amount of the protein contributed to the diet by green vegetables is very small. The main thing to remember is that they are quite able to take care of themselves so far as quantity of protein is concerned.

Our information regarding the quality of proteins in fresh vegetables is scanty, but the leaf proteins are thought to be, weight for weight, of better quality than seed proteins. Potato protein is adequate for maintenance but not for growth.

PROTEIN IN DIFFERENT TYPES OF VEGETABLES AND FRUITS EXPRESSED AS "SHARES" PER 100 CALORIES

Fresh Fruit "Shares"		Root Vegetables "Shares"		Fresh Green Vegetables "Shares"		Dried Legumes "Shares"	
Dates	0.24	Carrots	0.97	Peppers	1.84	Beans, Lima	2.32
Apples	0.26	Parsnips	0.99	String beans	2.22	Beans, kidney	2.33
Prunes	0.28	Potatoes	1.06	Lettuce	2.51	Cowpeas	2.48
Pineapple	0.37	Rutabagas	1.26	Peas	2.77	Beans, navy	2.61
Pears	0.38	Onions	1.32	Brussels sprouts	2.92	Peas, split	2.79
Grapefruit	0.46	Turnips	1.32	Chard	3.35	Lentils	2.95
Plums	0.48	Beets	1.39	Spinach	3.51		
Bananas	0.53						
Figs	0.54						
Peaches	0.68						

The dried legumes have nearly the same proportion of protein to total calories as the green vegetables, but are practically more important sources because of the larger number of calories consumed. To eat 100 calories of navy beans is not generally considered any greater task than to consume 25 calories of string beans. As these two foods have nearly the same amount of protein per 100 calories, the practical result would be 2.6 "shares" of protein from the navy beans and only 0.6 of a "share" from the string beans. The

quality of legume proteins differs with the species. Navy beans (*Phaseolus vulgaris*) and cowpeas (*Vigna sinensis*) have proteins which require cooking to develop their full nutritive value, and even then they will not support growth without reinforcement, being deficient in the essential amino acid cystine. Soy beans are complete, but must be cooked to support growth. The proteins of common garden and field peas (*Pisum sativum*) are complete and will support growth without cooking.

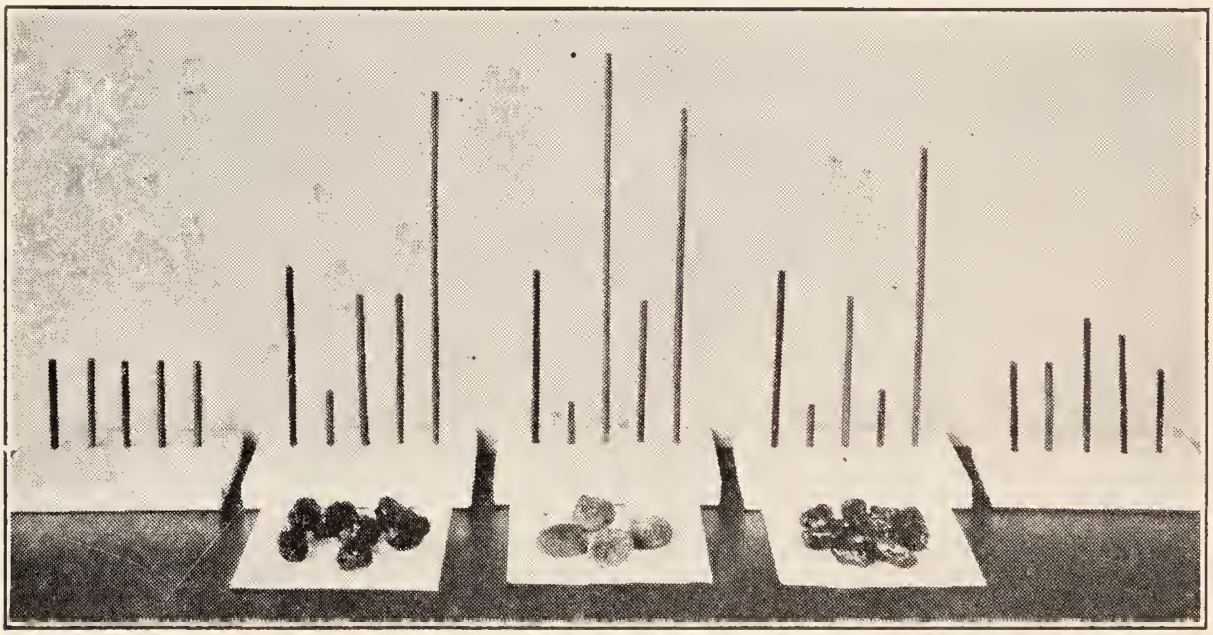


FIG. 77.—"Shares" Contributed to the Diet by Individual Portions of Prunes, Figs and Dates, Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a Child (right).

	Standard Portion of Adequate Diet for Adult	*Prunes* (7 large)	*Figs* (4 large)	*Dates* (9)	*Standard Portion of Adequate Diet for Child*
Calories [1]	1.0	2.0	2.0	2.0	1.0
Protein	1.0	0.6	1.0	0.5	1.0
Calcium	1.0	1.6	4.4	1.6	1.5
Phosphorus	1.0	1.6	1.6	0.7	1.3
Iron	1.0	4.0	3.8	3.4	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B and C

	Prunes	*Figs*	*Dates*
Vitamin A	++	Unknown	Unknown
Vitamin B	++	Unknown	Unknown
Vitamin C	—	Unknown	Unknown

Ash Constituents

As sources of mineral elements vegetables are of very great importance. Along with those elements needed in relatively large amounts, such as calcium, phosphorus, and iron, we receive in these foods a number of others, such as iodine, which although present in minute quantities are of real significance, as has already been pointed out in Chapter VIII.

As a source of calcium for growth, milk stands preeminent, but in the diet of the adult, the calcium of vegetables has been found to be efficient in maintaining calcium equilibrium. Leaf and stem vegetables are generally richer in this element than other vegetables or fruits, but carrots among root vegetables and oranges, figs, and pineapple among fruits yield enough to teach us that it is worth while to learn as much as possible about individual foods, and not trust entirely to arbitrary divisions based on botanical function.

Calcium in Different Types of Vegetables and Fruits Expressed as "Shares" per 100 Calories

Fresh Fruits	"Shares"	Root Vegetables	"Shares"	Leaf and Stem Vegetables	"Shares"	Dried Legumes	"Shares"
Bananas	0.39	Potatoes	0.69	Brussels sprouts	3.74	Beans, Lima	0.87
Apples	0.52	Tomatoes	2.17	String beans	4.78	Cowpeas	1.26
Prunes	0.78	Beets	2.78	Asparagus	5.34	Lentils	1.35
Dates	0.83	Parsnips	3.96	Cabbage	6.22	Beans, kidney	1.74
Raisins	0.83	Carrots	5.39	Lettuce	9.74	Beans, navy	2.04
Pears	1.04			Spinach	12.22		
Cranberries	1.70			Chard	17.09		
Grapefruit	1.73			Cauliflower	17.52		
Pineapple	1.78			Celery	18.30		
Figs	2.21						
Oranges	3.83						

As sources of iron the green vegetables are extremely important foods. They not only yield the needed iron,

but provide favorable conditions for its absorption from the digestive tract and for its use in building hemoglobin. Fruits are on the whole less dependable sources

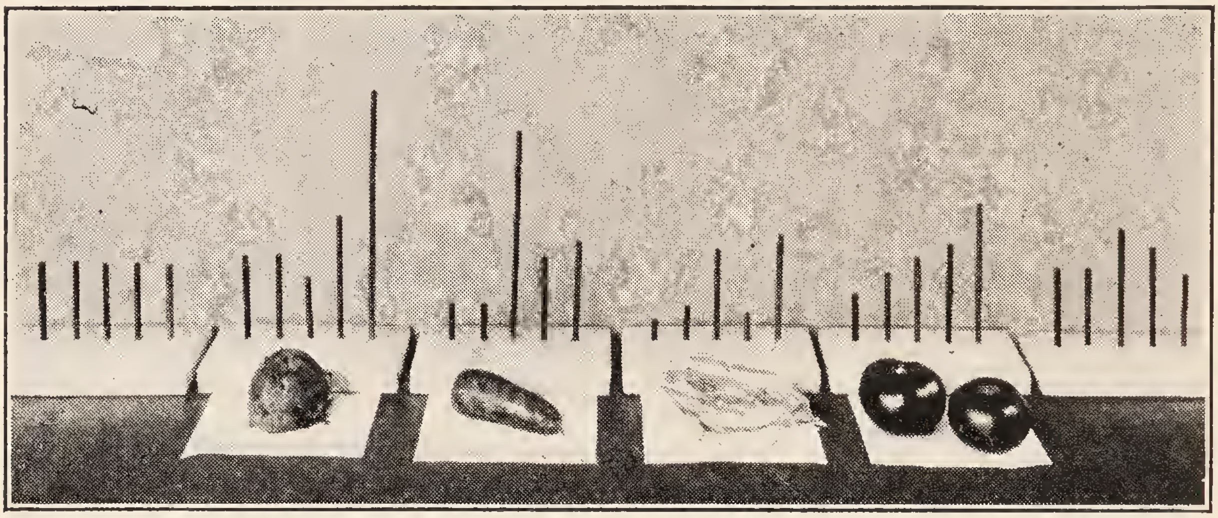


Fig. 78.—"Shares" Contributed to the Diet by Individual Portions of Potatoes, Carrots, Cabbage and Tomatoes. Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a child (right).

	Standard Portion of Adequate Diet for Adult	*Potato* (5.3 oz.)	*Carrot* (5.0 oz.)	*Cabbage* (2.2 oz.)	*Tomatoes* (7.7 oz.)	*Standard Portion of Adequate Diet for Child*
Calories[1]	1.0	1.0	0.5	0.2	0.5	1.0
Protein	1.0	1.1	0.5	0.4	0.8	1.0
Calcium	1.0	0.7	2.7	1.2	1.1	1.5
Phosphorus	1.0	1.6	1.1	0.4	1.3	1.3
Iron	1.0	3.2	1.3	1.4	1.8	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B, and C

	Potatoes (cooked)	*Carrots* (young, cooked)	*Cabbage* (raw)	*Tomatoes* (raw or canned)
Vitamin A	+	+++	+	++
Vitamin B	++	++	++	++
Vitamin C	+	+	+++	+++

of iron than of calcium, not all of them carrying enough to balance their own calories, and few carrying any considerable surplus. Fresh fruits with more than two shares of iron per 100 calories are cranberries, huckleberries, pineapple, and strawberries. Strictly speaking, the tomato, which is really a fruit, should also be in-

cluded. Among the dried fruits, raisins only have more than two iron shares per 100 calories.

IRON IN DIFFERENT TYPES OF VEGETABLES AND FRUITS EXPRESSED AS "SHARES" PER 100 CALORIES

Fresh Fruits "Shares"		Root Vegetables "Shares"		Leaf and Stem Vegetables "Shares"		Dried Legumes "Shares"	
Grapes	0.62	Parsnips	1.80	String beans	5.30	Beans, Lima	4.00
Oranges	0.78	Turnips	2.55	Celery	5.40	Beans, navy	4.06
Pears	0.94	Beets	2.60	Brussels sprouts	6.98	Beans, kidney	4.32
Apples	0.96	Carrots	2.66	Cabbage	6.98	Lentils	4.94
Grapefruit	1.16	Potatoes	3.12	Lettuce	7.34		
Bananas	1.22			Dandelion greens	8.80		
Dates	1.72			Asparagus	9.02		
Figs	1.90			Spinach	30.12		
Prunes	2.00						
Pineapple	2.32						
Raisins	2.78						

Vitamins

One of the most weighty reasons for including vegetables and fruits in the diet is to insure a liberal supply of each of the necessary vitamins. Knowledge of the vitamin content of raw foods of this class and of the changes brought about by storing, cooking, canning, drying, etc., is therefore necessary to intelligent administration of any dietary. As yet quantitative investigations have not proceeded far, but a table is available in the appendix giving the relative yield of most common foods, and the discussion of sources of the vitamins in Chapter X may also be referred to.

The richest plant sources of vitamin A are thin green leaves. Of these, spinach has the highest content of any common vegetable which has been investigated, being weight for weight, when fresh, a little richer than butter. Bleached leaves, such as the inner leaves of

cabbage and head lettuce, have much less than similar leaves when green. Seeds are relatively poor in vitamin

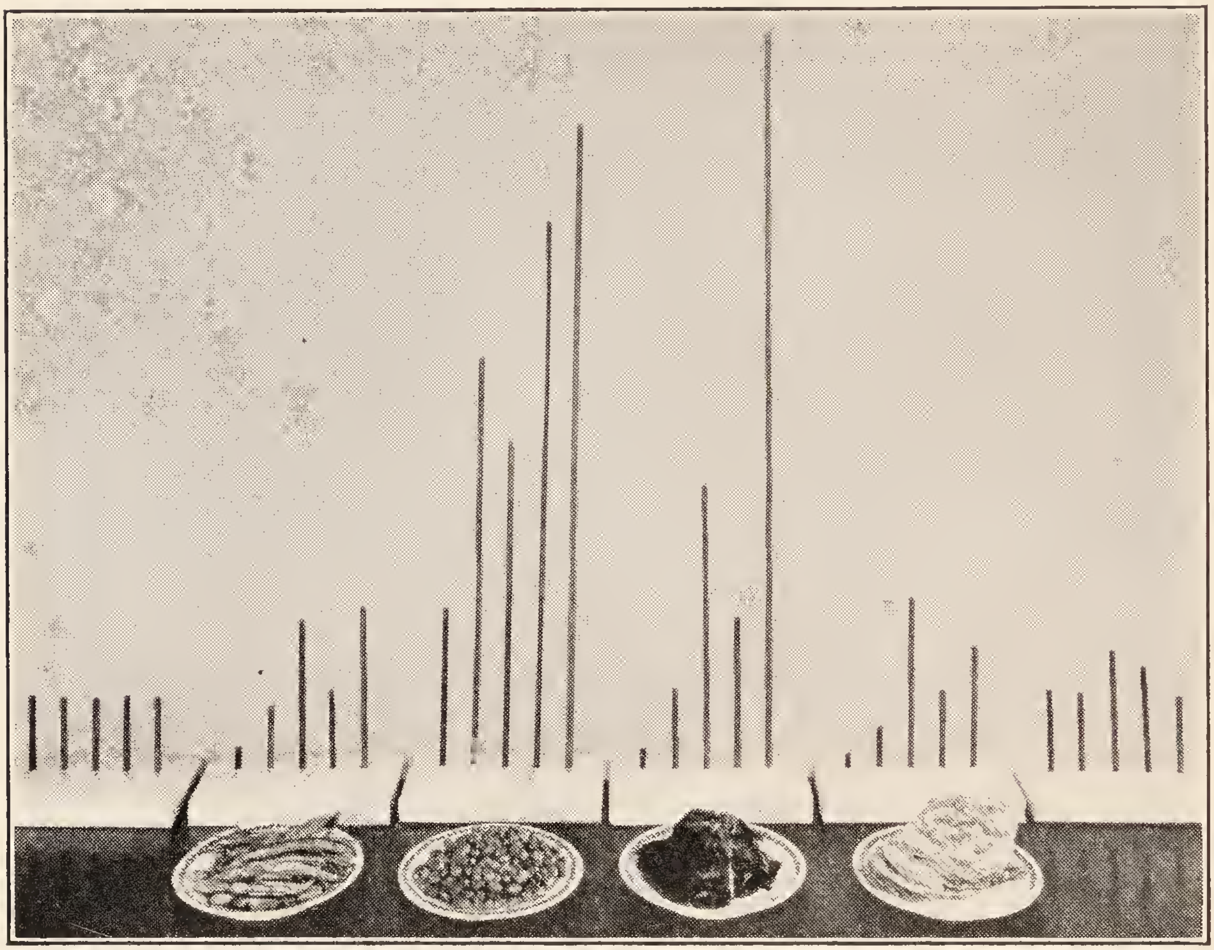


FIG. 79.—"Shares" Contributed to the Diet by Individual Portions of String Beans, Baked Beans, Spinach and Lettuce, Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a Child (right).

	Standard Portion of Adequate Diet for Adult	*String Beans* (3.6 oz.)	*Baked Beans* (canned, 1 cup)	*Spinach* (4.4 oz.)	*Lettuce* (3.7 oz.)	*Standard Portion of Adequate Diet for Child*
Calories [1]	1.0	0.4	2.0	0.3	0.2	1.0
Protein	1.0	0.8	5.2	1.0	0.5	1.0
Calcium	1.0	1.9	4.0	3.6	2.0	1.5
Phosphorus	1.0	1.1	6.2	1.9	1.0	1.3
Iron	1.0	2.1	8.1	9.0	1.5	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B, and C

	String Beans (cooked)	*Baked Beans* (canned)	*Spinach* (cooked)	*Lettuce* (raw)
Vitamin A	++	+	+++	+
Vitamin B	++	+++	+++	++
Vitamin C	Not determined	—	+	+++

A, but young green peas are an exception, being weight for weight about twice as rich as green string beans. Roots and tubers generally contain little A, but carrots must be specially noted because they are nearly as rich as spinach; likewise sweet potatoes, which are about the equivalent of green peas. Fruits resemble roots and tubers, but special mention must be made of tomatoes, which weight for weight are about as rich as lettuce.

Vitamin B is so widely distributed in vegetables and fruits that almost any assortment of these will insure a sufficiency of this vitamin in a diet which is adequate in all other respects. There seems to be no marked difference in the yield of leaves and fruits as compared with roots and tubers; weight for weight, they are about as rich as milk. Here again spinach is higher than most leaves. Seeds resemble one another, and on the basis of weight are five or six times as rich as milk.

Vitamin C is obtained almost exclusively from vegetables and fruits, and is so irregularly distributed and so easily destroyed that one must know definitely whether the vitamin occurs in the food material in question and also in each instance the effect of storing, canning, cooking, or drying. Cabbage is an excellent antiscorbutic when raw, but loses its value rapidly in the process of cooking; tomatoes on the other hand lose but little in the short time required for cooking and canned tomatoes may be considered a staple antiscorbutic.

The citrus fruits, especially oranges, lemons, and grapefruit, not only have a relatively high content of vitamin C in their fresh state, but retain their antiscorbutic property when properly dried. A concentrated preparation of lemon juice has been prepared in tablet

form and found to retain its antiscorbutic property over a year when stored at room temperature. Lime juice is only about one-fourth as efficient as lemon juice and preserved lime juice is not dependable. Tomatoes, which are really a fruit, are very similar to orange and lemon juice as regards vitamin C. Grapes have little vitamin C and grape juice practically none. Raw bananas and apples have about the same value as an equal weight of cooked potato. Although these fruits are of distinctly lower value than the citrus fruits, they may be consumed in sufficient quantities to make them significant, as has already been pointed out in Chapter X.

Fresh greens of all sorts are doubtless of much value, though not many have been quantitatively studied. Spinach is as rich, weight for weight, as orange juice, and although there is considerable loss even with quick cooking, the larger quantity which can be consumed offsets in considerable degree such destruction of the vitamin as is brought about by the heating. In commercial canning, spinach has been shown to lose less vitamin C than in home cooking. In general vegetables should be cooked as quickly as possible to conserve vitamin C, time being a factor as well as temperature.

Certain root vegetables rank high as sources of vitamin C, especially rutabagas, carrots, onions, and potatoes. Carrots have the advantage of being palatable raw, and the juice of the uncooked yellow turnip has been satisfactorily used as an antiscorbutic for children when no more convenient source was available.

Mature seeds have little or no vitamin C but sprouted seeds are an important source in some parts of the world,

such as China. Immature green peas are fairly rich in C, and when canned retain a considerable part of their original supply.

Summary

Vegetables and fruits vary greatly in energy value. Only the dried seeds of legumes and sweet dried fruits approximate cereals in calories per pound. The relative value of the others depends chiefly on the amount of starch or sugar present. Green leaves and stems have little fuel value.

With the exception of dried legumes, few fruits or vegetables are used in quantities which make their protein content very significant for the diet as a whole. The quality of the legume proteins tends to be rather poor, but soy beans and peas have proteins adequate for growth. Most vegetables carry at least enough protein to balance their own calories from the quantitative standpoint, but fruits do not.

As sources of mineral elements of the many kinds required by the body, vegetables and fruits deserve a higher place in the diet than has generally been accorded them in the past. Green vegetables are especially valuable as sources of iron and for providing favorable conditions for its absorption and use in building hemoglobin. The ash of fruits is usually of such character as to help greatly in maintaining the normal neutrality of the blood.

As sources of vitamins, vegetables and fruits are almost indispensable. Thin green leaves are as a rule rich in vitamins A, B, and C. Fruits and vegetables which are eaten raw usually contribute significant

amounts of vitamin C. Some lose little in cooking; others much or practically all. Vitamin B is more evenly distributed than A or C, and will probably be adequate if any good assortment of vegetables and fruits is regularly consumed.

"Contrary to the supposition of former times, it now appears that a diet consisting largely of breadstuffs and cereals is more effectively supplemented by vegetables than by meat. This is true not only as regards the previously known factors of the food supply, but also because of the richness in vitamins of the fruits and vegetables and because of their beneficial influence upon intestinal hygiene and upon the elimination of wastes from the body." [1]

Section 5

EGGS, CHEESE, NUTS, MEAT AND OTHER FLESH FOODS

Eggs

Among the foods so far considered none but milk can be designated an outstanding source of protein. Cereals and many vegetables have protein enough to "balance" their own calories, but with the exception of the legumes none will have large surpluses to make up for the shortcomings of fuel foods totally devoid of protein, such as fats and sugars. A quart of milk in the diet of a child whose body weight is under 60 pounds (a weight not attained much before the seventh year) will amply safeguard the diet as to total protein, but

[1] Sherman, H. C., and Smith, S. L. *The Vitamins*, page 230. Chemical Catalog Co., Inc. (1922).

subsequently there will be need of other foods to reinforce the diet in this direction. In making a selection from available sources of protein it is wise to pay

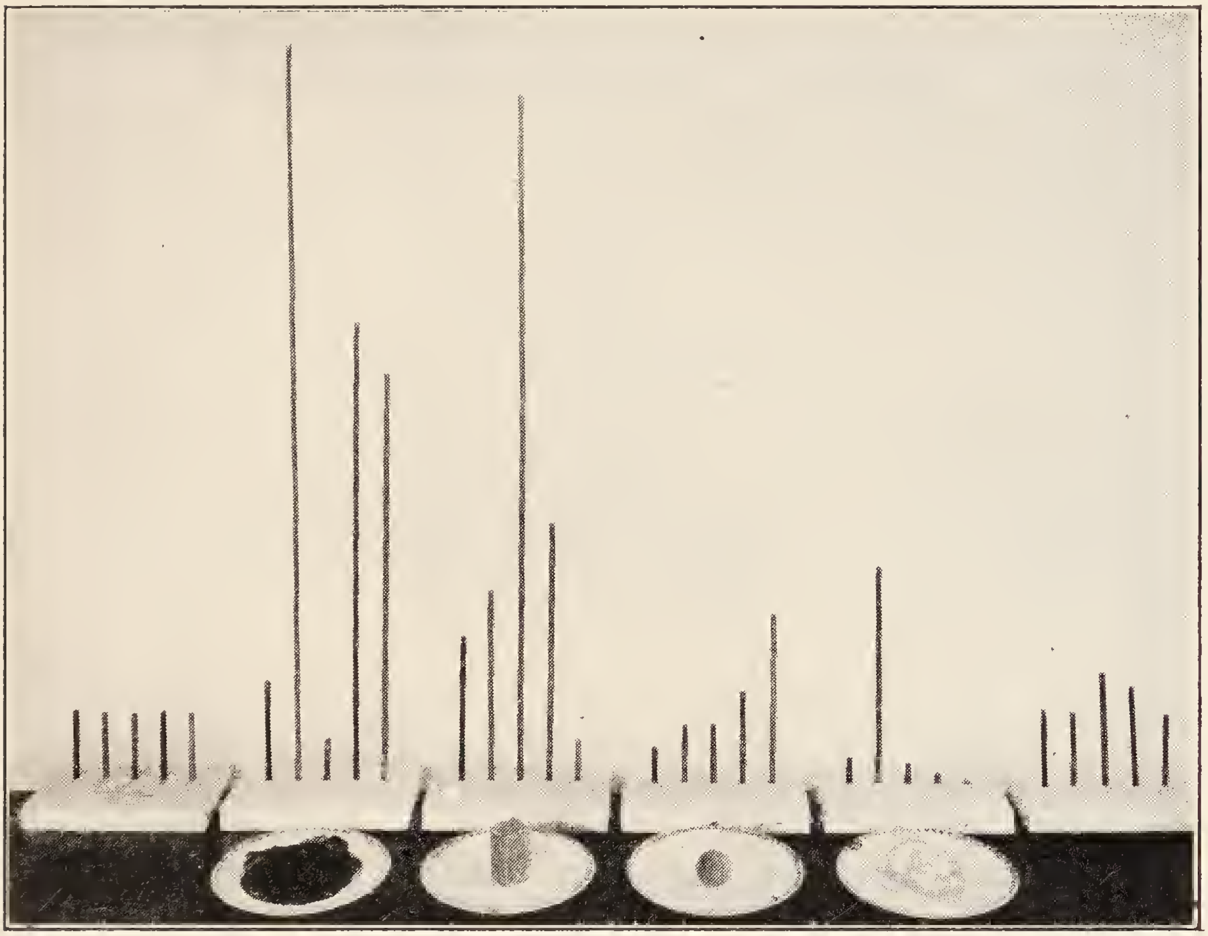


FIG. 80.—"Shares" Contributed to the Diet by Individual Portions of Lean Beef, American Cheese, Egg yolk and Egg white. Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a Child (right).

	Standard Portion of Adequate Diet for Adult	*Lean Beef* (4 ounces)	*American Cheese* (1.6 cubic inches)	*Egg Yolk* (one yolk)	*Egg White* (one white)	*Standard Portion of Adequate Diet for Child*
Calories [1]	1.0	1.5	1.0	0.5	0.3	1.0
Protein	1.0	8.5	2.6	0.8	2.9	1.0
Calcium	1.0	0.5	9.2	0.8	0.3	1.5
Phosphorus	1.0	5.0	3.5	1.3	0.2	1.3
Iron	1.0	4.5	0.6	2.3	0.1	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B, and C

	Lean Beef	*American Cheese*	*Egg Yolk*	*Egg White*
Vitamin A	+	++	+++	—
Vitamin B	++	—	++	Unknown
Vitamin C	—	Unknown	—	—

attention to other growth-promoting substances which may be secured incidental to the protein. From this point of view, the egg would be the first choice, and especially the yolk, which is rich in all substances necessary for growth except calcium and vitamin C. In fact, a small amount of egg yolk may profitably be included in the diet of breast-fed babies as soon as weaned, and in that of artificially fed babies earlier in the first year entirely for the sake of other nutritive factors beside protein. By the time the child is three or four years old, the whole egg may become a regular part of the daily diet. Careful observation of a number of children has shown that such reinforcement results in better physical condition and better utilization of iron.

The chief protein of the egg yolk (ovovitellin) resembles casein of milk in its amino acid content and so does that of the white (ovalbumin). Both are therefore complete proteins independently capable of supporting growth and valuable in bringing to full efficiency proteins of lower value such as the cereal proteins. Next to milk, eggs are the most important protein-bearing food in the diet of the growing child.

The ash constituents of the egg are mainly found in the yolk, which carries more calcium and phosphorus and nearly five times as much iron as needed to balance its own calories, as shown in Fig. 73. The iron in egg yolk is in a form particularly valuable, and the quantity compares very favorably with that in other foods which may be considered significant sources of iron, as the following table demonstrates:

"Shares" of Iron in One Egg Yolk Compared with those in Amounts of other Foods Consumed with Similiar Ease

Food Materials	Amount	"Shares" of Iron
Egg yolk	1 yolk	2.3
Spinach, steamed	1/3 cup	4.5
Wheat, shredded	1 biscuit	2.5
Peas, fresh	½ cup	2.4
Potato	1 small	1.6
Beef, lean	1 ounce	1.1
Beans, string	½ cup	1.4
Oats, rolled	¼ cup	1.4
Farina, dark	1/8 cup	2.1
Carrot, diced	½ cup	0.8
Lettuce	1/8 large head	0.7

Egg yolk is an excellent source of vitamins A, B, and D. According to Sherman one egg has about the same amount of B as ¼ cup of fresh milk and about as much vitamin A as three cups of milk. The amount of vitamin D in egg yolk has been found sufficient to safeguard infants during the late winter months against rickets when one yolk a day was fed. Eggs cannot be regarded as a substitute for milk, but may be advantageously used in addition to it. They admirably reinforce milk as to iron, as will be seen from the following table in which one egg is combined with a quart of milk:

"Shares" of Protein, Calcium, Phosphorus, and Iron in 100 calories of Milk, of Egg, and of Milk and Egg Combined in Proportions of one Egg to a Quart of Milk

	Milk "Shares"	Egg "Shares"	Milk and Egg (In Proportions of One Egg to one Quart of Milk), "Shares"
Calories	1.0	1.0	1.0
Protein	1.9	3.6	2.0
Calcium	7.6	2.0	7.0
Phosphorus	3.1	2.8	3.0
Iron	0.7	4.1	1.0

Cheese

Of approximately two thousand tons of cheese manufactured annually in the United States the major portion is of the "American" variety. A pound of such cheese contains the casein and fat of a gallon of milk, together with traces of whey retained by the curd. It has about one-fourth of its calories in the form of protein and the other three-fourths in the form of fat. The milk sugar is mostly withdrawn in the whey, or changed to lactic acid in the ripening process. The calcium, phosphorus, and iron of the milk are retained in the cheese and also a large part of the vitamin A. The contributions to the diet made by two cubic inches of American cheese are graphically portrayed in Fig. 80, and the striking resemblance between the contributions of this amount of cheese and those made by a glass of milk will be readily perceived by reference to Fig. 73, page 315.

Such a concentration of the most important nutritive elements of milk in a food of excellent keeping qualities entitles cheese to a place in the diet which is not always fully appreciated. Its strong flavor precludes its use in many of the ways in which milk is practical and makes it more akin to meat in regard to its place on the menu, but as a substitute for meat it gives a much better return in nutritive value for the money expended, and is particularly valuable as a source of calcium in the diet of adults who have not acquired the habit of using milk freely.

Because of its flavor cheese is often regarded as a condiment and served with other foods merely to add zest to a meal. It should be remembered, however,

that cheese is a concentrated food and is properly used in the diet much as meat would be. Because of its texture and its high proportion of fat calories to total calories it is digested best when used with bread or other cereal foods, and when very thoroughly masticated or cooked in such a way as to be soft and not leathery. Too large a quantity will sometimes prove irritating to the stomach because of small amounts of certain substances developed in the ripening process, but knowledge of its concentrated nature should lead to due restraint. Half a pound of cheese will provide sufficient protein of the best quality for an average man for a day, and fully one-third of his total calories. The simple addition of a pound of whole-wheat bread and a couple of pounds of fruit will result in a diet adequate for an adult in every respect and at a most moderate outlay of money and effort.

Nuts

Nuts are often regarded as a mere adjunct to the dietary to be nibbled between courses at dinner, to add interest to afternoon tea, or to be eaten between meals for pure amusement. Thus used they may prove disturbing to digestion or furnish calories in excess of body needs, for they contain chiefly protein and fat and digest rather slowly and their fuel value is very high. About half an ounce of almost any one of our common nuts is sufficient to yield 100 calories. This means the small matter of two brazil nuts, eight to ten filberts, half a dozen medium-sized pecans or a dozen peanuts. Chestnuts are the only notable exception to this concentration of energy, about three

times as much by weight being required to get 100 calories from them as from other common nuts. In their yield of protein, fat, and carbohydrate, chestnuts are almost exactly like graham crackers, as will be seen from Fig. 81; when dried they have the same

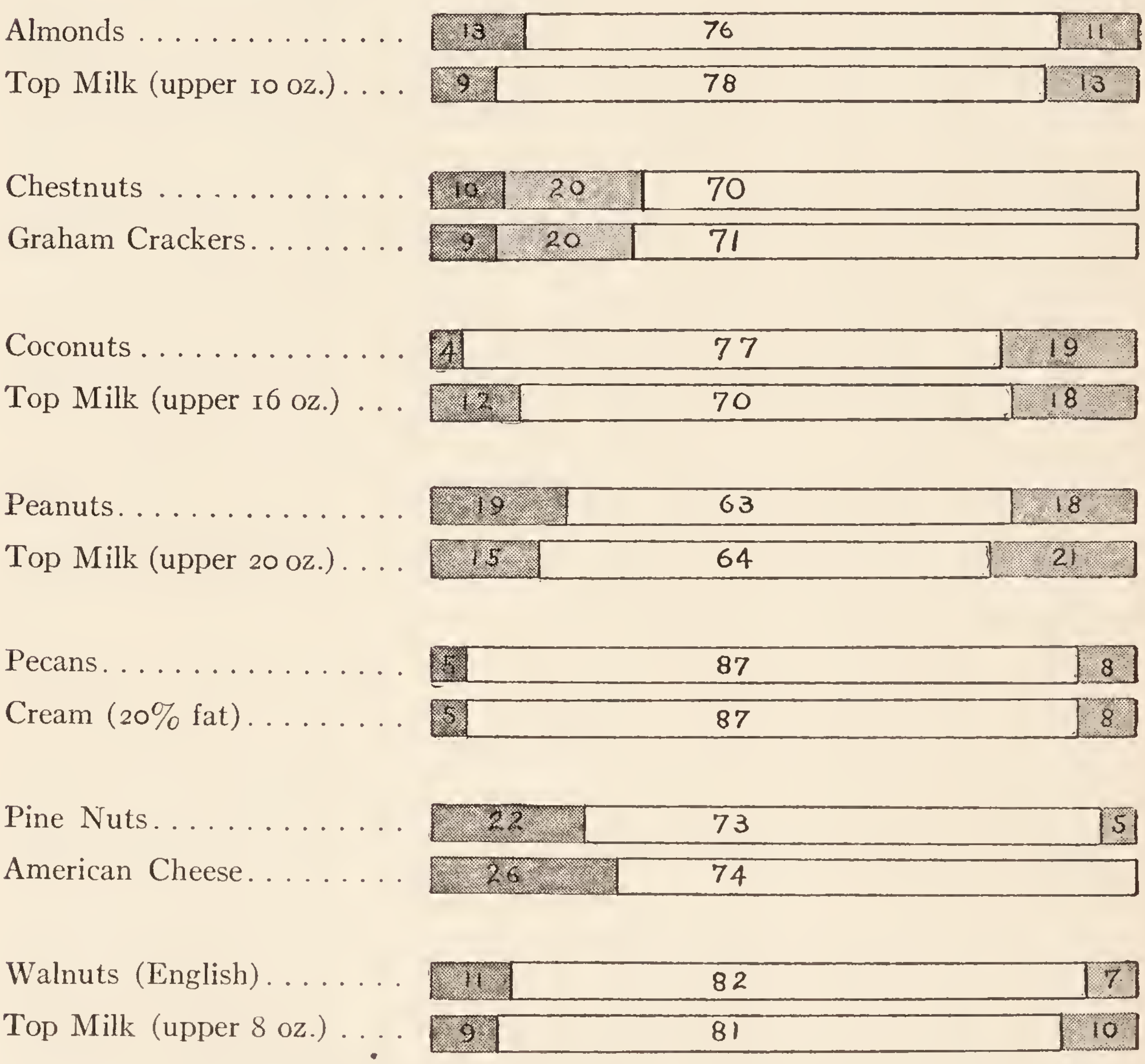


FIG. 81.— This chart shows the number of calories from protein, fat and carbohydrate respectively in a 100-calorie portion of some common nuts and the food which they most closely resemble in distribution of calories.

number of calories per pound as the crackers. Our other common nuts yield at least twice as many calories in the form of fat as of protein and carbohydrate together, and resemble ordinary gravity cream or the rich milk secured by removing a certain num-

ber of ounces from the top of a quart bottle which has been standing long enough for the cream to rise. The kind of cream or milk which some of our most widely used nuts closely resemble is also shown in Fig. 81.

The proteins of nuts of various kinds, including almonds, coconuts, peanuts, and pecans, have been found to be adequate for growth, and chemical analyses of individual proteins from some of these have shown an amino acid assortment rather similar to that of meat. Peanut flour, made from the press cake left after the extraction of the peanut oil, has been found an excellent supplement to the proteins of wheat, a bread made with 75 per cent wheat flour and 25 per cent peanut flour giving a mixture in which the protein was adequate for the normal growth of white rats.

In nuts as ordinarily eaten, the proportion of protein to total calories is generally too low to expect them to contribute very significant quantities of protein to the diet. Exceptions are almonds, which have one and three-tenths shares of protein for every calorie share, peanuts with nearly two protein shares, and pine nuts (pignolias) with two and one-quarter shares per calorie share. These foods are therefore of some importance as sources of protein. The combination of two energy shares of bread (200 calories) with one of peanuts (100 calories) results in a mixture with such proportions of protein, fat, and carbohydrate as characterize a good mixed diet, and with one and one-half protein shares for each energy share, guaranteeing adequacy both as to quantity and quality of protein at a very moderate cost.

As sources of ash constituents nuts as a class are

not of much importance because here, again, the amount of ash per energy share is usually less than one. Among nuts for which we have ash analyses, peanuts and almonds are outstanding in regard to phosphorus, having one and two-thirds shares per energy share, and almonds are unique in furnishing slightly more than their own quota of iron.

Nuts are poor in vitamin A and the oil pressed from them is practically devoid of it. They resemble the cereal grains as sources of vitamins B and C, having a considerable supply of B and practically none of C.

Compared with cream and top milk, which they so closely resemble in regard to their energy yield, they furnish protein in relatively small amounts similar in quantity and probably not quite so good in quality. They are distinctly inferior as sources of calcium, not even excepting almonds which are far above the nut average. A number of them resemble thin cream in phosphorus content, and all of them carry more iron than cream, but, excepting almonds again, not enough to balance their own calories. As sources of vitamins they are far inferior to cream as regards vitamin A and never superior with regard to B and C.

A Comparison of Some Common Nuts and Gravity Cream Expressed in "Shares"

	Calories	Protein	Calcium	Phosphorus	Iron
Cream (18% fat)	1.0	0.5	2.2	1.0	0.2
Almonds	1.0	1.3	1.6	1.6	1.2
Chestnuts	1.0	1.0	0.6	1.0	0.6
Coconuts	1.0	0.4	0.3	0.4	0.6
Peanuts	1.0	1.9	0.6	1.7	0.7
Pecans	1.0	0.5	0.5	1.0	0.7
Walnuts, English	1.0	1.0	0.6	0.3	0.6

Because of their dense nature, nuts are not easily penetrated by the digestive juices. To be readily digested they need therefore to be very thoroughly masticated or else finely ground. Peanut butter is an excellent example of a nut prepared in a way to increase ease of digestion. Nuts should also be combined with foods low in fat if they are to be consumed in any considerable quantity; otherwise their high fat content makes the total fat of the diet too great for speedy gastric digestion. When these considerations are given due weight, nuts are an excellent kind of food, and may well be used more freely than is generally the practice. A meal which requires no cooking and is adequate in all respects except vitamin C can be secured from bread and butter, dried fruit, and nuts. The inclusion of a little orange juice or lemon juice would add the lacking vitamin. Such a meal is most economical, both as regards initial outlay and the labor involved in preparation, serving, and dishwashing. Many busy people could well adopt such a meal once a day. A luncheon of this character, with sufficient food for a sedentary adult, is given in detail above. It will be noted that every energy share in the

Luncheon with Peanuts and Figs

	Calories "Shares"	Protein "Shares"	Calcium "Shares"	Phosphorus "Shares"	Iron "Shares"
Bread, entire wheat	3.0	4.8	2.6	4.8	3.9
Butter	1.0	—	—	—	—
Peanuts	2.0	3.8	1.1	3.3	1.4
Figs	2.0	1.1	4.4	1.7	3.8
Total	8.0	9.7	8.1	9.8	9.1
Average	1.0	1.2	1.0	1.9	1.1

mixture carries its own quota of protein, calcium, phosphorus, and iron. The butter furnishes vitamin A, and each food except butter some vitamin B.

Meat and Other Flesh Foods

At the present time Americans spend more money for meat than for any other one type of food. According to Sherman's analysis of 224 typical family dietaries an average of one-third of the food money is invested in meat, with a return of less than one-fifth of the total calories. The meat consumption of Americans is estimated to be about 178 pounds per capita per year, or nearly half a pound apiece every day for each man, woman, child, and infant in arms. As mere infants and some folk older eat none and some others very little, it follows that many must have a great deal. Is this expenditure of so much money for meat wise? Does it help to guarantee to the American people well-balanced diets? The only way to answer these questions is by careful study of the nutritive value of the principal flesh foods. In connection with the prevailing market meats, beef, veal, mutton, lamb, and pork, we may also discuss poultry, game, fish and shellfish, since nutritionally they have the same characteristics. For the most part, Americans eat muscle tissue to the exclusion of other parts of the animal. Oysters and sardines are the only animal foods of any considerable importance in which the whole body is consumed. This is in marked contrast to the habit of carnivorous animals and of people living chiefly on animal food, none of whom let any part go to waste.

All kinds of flesh foods contain protein and usually fat; the fat varies greatly in amount with the species of animal and also in case of the larger creatures with the cut The amount of fat chiefly determines the proportions of other substances, the fat-free flesh being quite uniform in composition. The distribution of calories between fat and protein in flesh foods of various kinds is shown in the following table. Many have more fat than full cream cheese.

Distribution of Calories in 100–Calorie Portions of Lean Meats

	Calories Protein	Fat Calories
Cod, steak	92	8
Chicken broilers	80	20
Tuna fish	69	31
Veal, leg, lean	69	31
Chicken heart	62	38
Halibut steak	60	40
Herring	55	45
Beef, lean	54	46
Salmon, fresh	43	57
Mutton, leg, lean	41	59
Pork, loin chop, lean	32	68
Ham, lean	30	70

The amount of any mineral element in meat or fish is proportional to the amount of protein present rather than to the total calories. Lean meats are therefore richer in ash constituents than fat meats, and the higher the percentage of fat, the fewer shares of any mineral element per hundred calories.

All meats resemble the cereal grains in their content of calcium and phosphorus, being deficient in calcium, and rich in phosphorus. Codfish appears exceptionally rich in calcium, because it contains practically no fat.

Calcium and Phosphorus in Cereal Grains, Lean Meats and Fish

Cereal Grains "Shares"			Lean Meats "Shares"			Fish "Shares"		
	Calcium	*Phosphorus*		*Calcium*	*Phosphorus*		*Calcium*	*Phosphorus*
Buckwheat flour	0.5	1.5	Beef, lean	0.4	3.3	Cod, steak	1.0	5.6
Cornmeal	0.2	1.2	Chicken broilers	0.5	4.9	Halibut, steak	0.7	3.6
Oatmeal	0.7	2.3	Liver, beef	0.4	3.9	Herring	0.6	2.6
Wheat, entire	0.6	2.7	Veal, lean leg	0.4	4.3	Salmon, fresh	0.5	2.8
Rye flour	0.2	1.9						

The proteins of meats of all kinds are much alike in structure, containing a good assortment of essential amino acids, and hence capable of supporting growth, though in no way superior to milk and egg proteins. Like the latter they supplement the proteins of the cereal grains, but are not superior to either for this purpose. Quantitatively, lean meat is conspicuous for its high yield of protein, but fat rapidly reduces the proportion of protein to total calories, as the following table indicates:

Protein in Edible Portions of Lean Meat Expressed as "Shares" per 100 Calories

Cod steak	8.6
Chicken broilers	8.0
Tuna fish	7.0
Veal, lean leg	7.0
Halibut steak	6.1
Herring	5.5
Beef, lean round	5.5
Salmon, fresh	4.3
Mutton, leg	4.2
Lamb, leg	3.5
Pork, loin chop	3.2
Ham, lean	3.0

According to Sherman, the iron in meat of a given sort is also quite closely proportional to the protein content, and we may expect that iron will be high or low in a given piece of meat according as the fat is low or high. Internal organs, such as the heart, brain, liver, and kidney are much richer in iron than muscle tissue.

While strictly lean meat resembles the egg in having a higher iron content than the cereal grains, meats as ordinarily eaten and most fish are more like the grains than they are like the egg.

IRON IN MEATS AND FISH COMPARED WITH THE CEREAL GRAINS EXPRESSED IN "SHARES" PER 100 CALORIES

CEREAL GRAINS	"SHARES"	MUSCLE MEAT	"SHARES"
Wheat, entire	2.8	Beef, lean round	3.1
Barley, entire	2.3	Mutton, lean leg	3.1
Rye, entire	2.2	Lamb, lean leg	3.1
Oatmeal	1.9	Ham, lean	2.2
Rice, brown	1.2	Pork, loin chop	1.2

FISH	"SHARES"	INTERNAL ORGANS	"SHARES"
Cod steak	2.4	Liver, beef	12.7
Tuna, fresh	1.9	Heart, beef	8.7
Halibut steak	1.7	Kidney, veal	6.6
Herring, fresh	1.5	Eggs	4.1
Salmon, fresh	1.2		

As sources of vitamins, muscle meats resemble the cereal grains more closely than any other kind of food. They have little if any vitamin A or vitamin C, but are fairly good sources of vitamin B. Liver and kidney are good sources of vitamin A as well as vitamin B, and contain appreciable amounts of vitamin C, but sweetbreads are much like muscle tissue.

From the foregoing it is evident that, aside from total calories, the most significant contribution of ordinary meat to the dietary is protein. But it should be borne in mind that the amount of protein yielded by a lamb chop can be obtained from an egg equally well and from two level tablespoonfuls of peanut butter, or one and one-fourth ounces of cheese, or a glass of milk, at much less cost. The second most important contribution of meat is iron, but again, it has no monopoly of this important element; a quarter of a cup of cooked spinach or three-fourths of a cup of string beans or an egg yolk or two slices of whole wheat bread furnish quite as much as a lamb chop, and there is abundant evidence that they would be as efficient in building hemoglobin and usually less expensive, quite aside from the fact that they furnish the vitamins which the meat lacks.

The chief advantages of meat seem to be its palatability, ease of preparation for the table, and ease of digestion. For these reasons, some meat in the dietary is very acceptable. If the meat is used to increase the consumption of milk, vegetables, and fruits, and not to displace them, it may be a desirable though rather expensive addition to the diet.

Evidence is accumulating that liver is particularly favorable to hemoglobin formation, especially when used with an abundance of fresh fruits and vegetables.

Summary

Eggs, cheese, meat and other flesh foods are grouped together because they possess the common property of contributing to the diet proteins of the highest quality

in amounts which are absolutely as well as relatively significant. Nuts are also included in this group because their proteins are of good quality, and they have as much protein in proportion to total calories as fat meats.

Eggs in addition to protein are rich in vitamins A and B and in iron and phosphorus; they therefore serve like milk to reinforce the diet at several points and deserve special emphasis for their growth-promoting properties. American cheese represents a concentration of most of the protein, fat, calcium, phosphorus, and iron of the milk from which it is made. It also contains a large part of the vitamin A of the milk. Used interchangeably with eggs and meat as a source of protein, it adds calcium, in which meat is very deficient and eggs somewhat low. Meat in the American diet means chiefly muscle tissue, which unless very fat is high in protein, phosphorus, and iron, but very deficient in calcium and in vitamins A and C.

Liver and kidney are relatively rich in vitamins A and B, but like other meats need to be supplemented by milk or cheese for calcium, and by some fruit or vegetable for vitamin C. Liver is not only rich in iron but seems to have associated with it other substances favoring the utilization of the iron by the body. Just what these substances are is still unknown.

Section 6

FATS AND SUGARS

Fats and sugars are primarily sources of energy. Neither is essential to an adequate diet; as body fuel the two are interchangeable calorie for calorie under

ordinary living conditions. Yet the World War taught us what an important part these two kinds of food can play in sustaining or destroying the morale of a people. "The Europeans who are now so very short of fat are

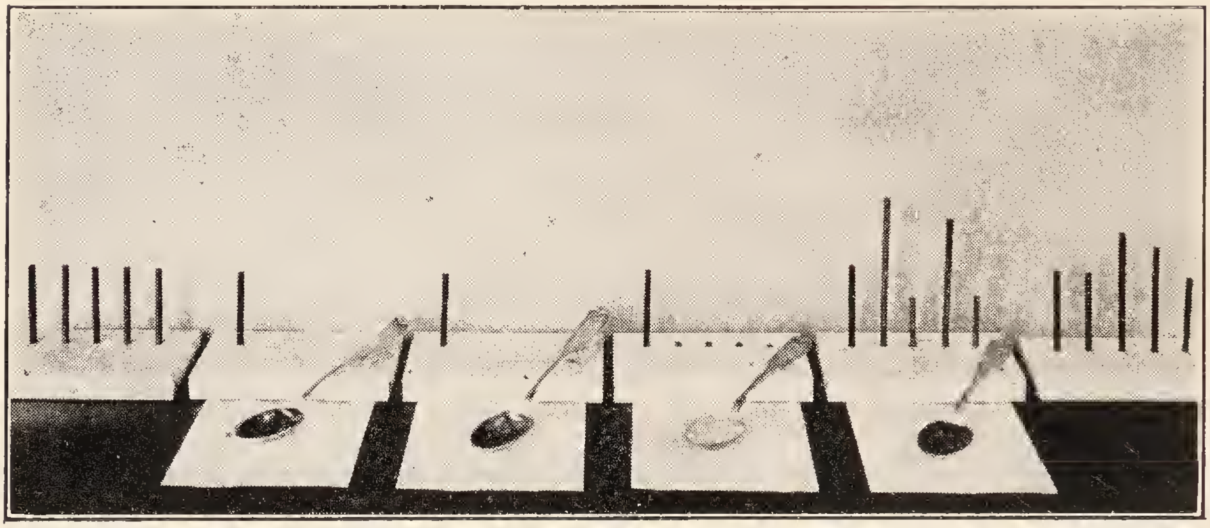


FIG. 82.—"Shares" Contributed to the Diet by One Tablespoon of Olive Oil, Cod-liver oil, Butter and Peanut Butter, Compared with a Standard Portion of an Adequate Diet for an Adult (left) and for a Child (right).

	Standard Portion of Adequate Diet for Adult	*Olive Oil*	*Cod-Liver Oil*	*Butter*	*Peanut Butter*	*Standard Portion of Adequate Diet for Child*
Calories [1]	1.0	1.0	1.0	1.0	1.0	1.0
Protein	1.0	—	—	—	1.9	1.0
Calcium	1.0	—	—	—	0.6	1.5
Phosphorus	1.0	—	—	—	1.7	1.3
Iron	1.0	—	—	—	0.7	1.0

[1] Read shares from left to right.

Relative Amounts of Vitamins A, B, and C

	Olive Oil	*Cod-Liver Oil*	*Butter*	*Peanut Butter*
Vitamin A	+	+++	+++	+
Vitamin B	—	—	—	++
Vitamin C	—	—	—	—

almost always hungry *even though their actual needs may be satisfied*." [1] In the United States where other food was abundant the saving of sugar to send overseas was accomplished only by a widespread and systematic

[1] *Food and the War*, page 109. United States Food Administration, Houghton Mifflin Co. (1918).

educational campaign in which "sugar-saving sweets" were constantly featured. In daily life, fats and sugars are not interchangeable. The diabetic, deprived of sugar, finds small consolation in a generous allowance of fat. Sugar does not altogether make good the feeling of emptiness on a ration devoid of fat. Even though they yield calories only, both are needed to make a perfectly satisfactory diet for most human beings.

Fats

Fat is the most concentrated form of body fuel, just as petroleum oil is the most compact fuel for the furnace. It takes only one half an ounce (one tablespoonful) of fat to yield 100 calories, and a person could get a whole day's fuel from three-quarters of a pound of fat if he were able to eat it. On the other hand, people of the Orient who on account of poverty live largely upon rice and in consequence have to eat a great quantity of food to secure sufficient fuel for their daily activities, develop distended abdomens. It would take nearly eight pounds of cooked rice to give the same number of calories as three-quarters of a pound of fat or oil. The latter would not fill a pint measure; the former pressed down would overflow a gallon measure. When for any reason a person is put on a milk diet for a considerable time, it is customary to add something to the milk to increase its concentration (such as more cream and more milk sugar), if any attempt is made to keep the energy intake up to what it would be on a full mixed diet. A man's energy requirement can be met by four to five quarts of milk per day if he is not doing extremely heavy manual labor, but it would be

more satisfactory to substitute for one quart of the milk a loaf of bread, which is comparatively dry, and for another quart, three ounces (six tablespoonfuls) of butter, thus reducing the volume without any change in energy value. For growing boys and girls and for men engaged in strenuous physical exercise, fat is almost essential if they are to get enough total calories.

Furthermore, fat gives the diet "staying" qualities. Other things being equal, one feels hungry sooner after a meal with little fat than after one in which it is liberally supplied. This is because fat leaves the stomach more slowly than proteins or carbohydrates and retards the digestion of either of these when used in combination with them. A mixture of fat and protein digests more slowly than one of fat and carbohydrate. Probably part of the popularity of meat is due to the fact that it is a protein-fat mixture in which the fat contributes very definitely to the feeling of satisfaction after the meal. The feeling of dissatisfaction among the Europeans on their low fat war ration was in large measure due to this effect of fat on digestion.

Too much fat may result in undue slowness of digestion and digestive upsets. How the fat is used in cooking also has much to do with its ease of digestion. Butter spread cold upon bread will digest more easily than butter fried into potatoes or incorporated in a sweet cake. The texture produced in the potatoes will not be favorable to rapid digestion and the fat will also exert its retarding influence. For a young child, the summation of effect is too great a risk. The sugar of cake is likewise a complicating factor. The same amount of sugar eaten pure at the proper time

might be diluted and passed along to be quickly absorbed, whereas the mixture is likely to be disposed of more slowly and not always harmlessly.

Used with proper discretion, all of our common food fats, both animal and vegetable, digest easily and completely. As sources of energy the different food fats are practically interchangeable and which we eat may be determined by preference and convenience. Some prefer olive oil, some pork fat; others revel in seal oil. The ancient Romans prized vegetable oil for food and butter for cosmetics. For a long time it was not known that there were fat-soluble vitamins, but now we have to consider fats also as possible sources of these dietary essentials. As Sherman has pointed out, "A surplus of vitamin A is not simply a reserve asset to be used at some future time but also actively increases the vigor and ability of the body to resist disease."[1] Careful consideration should be given to the bearing which this has upon the choice of fat. If a quart of whole milk is consumed daily, it will furnish as much vitamin A as about two ounces of commercial butter, and if in addition to the milk, green vegetables are consumed in liberal amounts, there need be no fear of a deficiency of vitamin A and the question of the kind of fat may be determined by other considerations. When, however, milk is less freely used (and a recent survey of 197 towns in 12 states shows the average per capita consumption to be far below any desirable amount, averaging slightly over half a pint),[2]

[1] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 459. The Macmillan Co. (1926).

[2] Crumbine, S. J. *A Campaign for Clean and Safe Milk*. Address at American Health Congress, May 22, 1926.

the habit of eating butter is certainly a safeguard of real importance. Vegetable oils, whether fluid or hardened by hydrogenation, are lacking in vitamin A and such animal fats as are used in butter substitutes have relatively little. Butter substitutes are such only in the sense of furnishing equivalent calories or something which can be used in the menu in the same way that butter is used unless by some special process vitamin A is added.

In some parts of the world cod livers are even richer sources of vitamin A than butter and are a staple article of the diet. But in this country, cod-liver oil is used in medicinal rather than dietary fashion as its flavor does not generally commend itself. In case of an option as to salad oil most people will take olive oil with very little vitamin A in preference to cod-liver oil so very rich in it. Yet a tablespoonful of cod-liver oil will furnish at least ten times as much vitamin A as the same amount of butter.

The administration of cod-liver oil to young children for the sake of its antirachitic vitamin has the additional advantage of increasing the intake of vitamin A. Since, weight for weight, egg yolk is about as rich in vitamin A as butter, the free use of eggs permits more choice as to the kind of fat. It is often better household economy to buy milk and a butter substitute than to spend the same amount of money for cream or butter. In butter substitutes refined vegetable oils, such as cottonseed, coconut, and peanut, and oils derived from beef or lard are so combined or treated as to produce the desired hardness and churned with milk or milk and butter to improve flavor and

texture. If more milk, green vegetables, and eggs can be bought by substituting such a product for butter, the diet will probably be improved. But if there is no danger of restricting the diet too much in some other direction, the purchase of butter as the chief food fat may be regarded as an investment with an assured return.

Sugars and Other Sweets

The common food sugars are cane sugar or sucrose, milk sugar or lactose, malt sugar or maltose, glucose or dextrose, and fructose or levulose. Cane sugar of commerce although widely distributed throughout the vegetable kingdom is derived from the sugar cane and sugar beet. Milk sugar differs chemically from cane sugar, being less sweet, less easily dissolved in water, and less easily fermented. Malt sugar is made by the partial digestion of starch. It does not appear in the ordinary market as pure malt sugar, but as a mixture of about half maltrose and half dextrin. This "malt food" is not very sweet and is popular for use in the modification of cow's milk for babies, either in conjunction with lactose or as a substitute for it. Glucose occurs widely in nature, but is obtained commercially by chemical treatment of starch. It does not appear in the food market as pure glucose but as "commercial glucose" or "corn syrup" which contains about as much dextrin as it does glucose. It is not very sweet, and table syrups made from it are flavored with the sweeter refiner's syrup from the manufacture of white cane sugar. Fructose occurs in many fruits, but honey is the only common food con-

taining a high percentage. Honey contains nearly equal proportions of fructose and glucose plus a little sucrose. Its flavor comes from substances found in minute quantities in the nectar of the flowers from which it is made. It has in addition traces of mineral matter.

Maple syrup and maple sugar consist of the concentrated sap of the sugar maple, and contain a certain amount of mineral matter as well as flavoring substances, the yield of calcium of maple syrup being 1.6 shares and of iron 2 shares per 100 calories.

Molasses is the mother liquor remaining after the removal of part of the cane sugar from the boiled-down juice of the sugar cane. In addition to the sugar which it contains, it has considerable mineral matter, yielding 3.2 shares of calcium, and 5 shares of iron per 100 calories.

Mixed syrups of various kinds are on the market and their ingredients may be learned from their labels.

Cane sugar resembles fat in being a concentrated form of body fuel, but differs from it in its effect on appetite and digestion. A scant two tablespoonfuls of granulated sugar will yield 100 calories and can be eaten in a meal without adding perceptibly to the volume of food consumed. In a cupful of lemon jelly, nine-tenths of the calories come from one-fourth of a cup of sugar, and in a cupful of vanilla ice cream nearly half the calories come from 2 tablespoonfuls of sugar. A cubic inch of chocolate fudge, in spite of milk, chocolate, and butter, has three-fourths of its calories in the form of sugar.

As body fuel, any kind of sugar is interchangeable

with starch, calorie for calorie. In the process of digestion, starch is converted to sugar and nowadays much corn starch is turned into glucose (corn syrup) before ever it is eaten. Sugar and starch are both

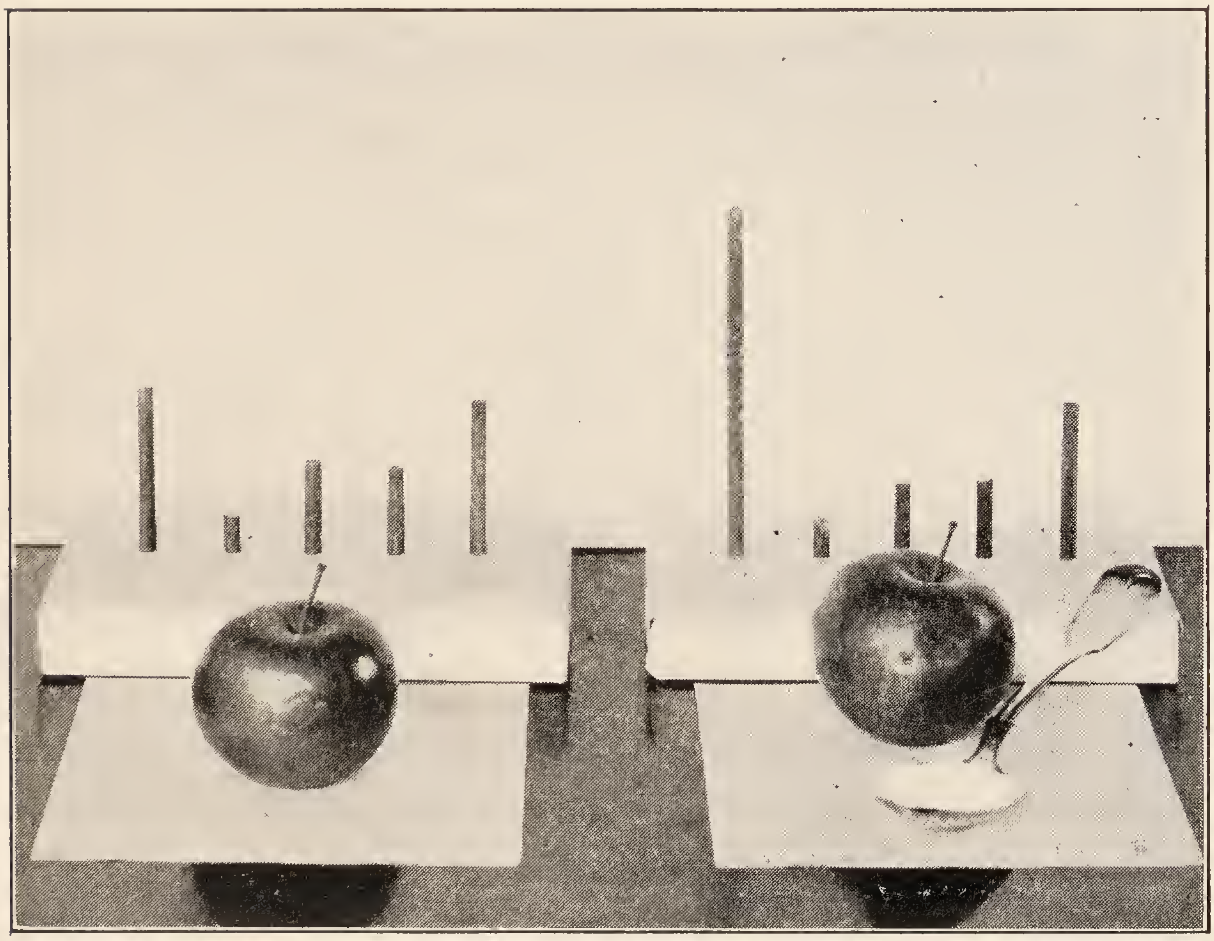


FIG. 83.—A comparison of a raw apple and the same apple plus the sugar that might be used in converting it into a baked apple.

	Raw Apple Number of Shares	*Apple and Sugar Number of Shares*
Calories	0.8	1.6
Protein	0.2	0.2
Calcium	0.4	0.4
Phosphorus	0.4	0.4
Iron	0.8	0.8

delivered to the blood stream from the alimentary tract as sugar. But no one would agree that starch and sugar are interchangeable in the menu; in fact we constantly add sugar to starch! The real reason for

eating sugar is its sweetness. "Sweeter than honey in the honeycomb" is a time-honored phrase of high appreciation. How many things lose their zest when sugar is lacking! Tea, coffee, cocoa, breakfast cereals, stewed fruits, may still be acceptable to a minority, but cake and cookies, pie and pudding, are unthinkable without sweetness. The bakery, the candy shop, and the soda fountain bear abundant testimony to our love of sweets. Four million tons of cane sugar a year for the American people—eighty-five pounds apiece for men, women, children, and infants, or nearly a quarter of a pound daily—what is it doing to the American dietary?

If too much sugar is allowed to displace other foods the diet will be deficient in the building and regulating materials which sugar lacks utterly. This influence of sugar may be illustrated in the difference in relative food values of a raw apple and the same apple with the sugar usually added in baking. Eating the baked apple may be more enjoyable, but the amount of other dietary essentials obtained in proportion to calories will be only half as much as in the raw apple. To use the least sugar which will produce an acceptable flavor is a good rule. Sugar creates an appetite, not for other foods, but for itself. The candy eater asks for more candy, not for bread and butter; the cake eater scorns the innocuous mildness of junket. Children who are allowed to eat candy whenever they feel like it are likely to be undernourished because the candy spoils their appetite for the foods they need for growth.

Sugar taken alone on an empty stomach is directly irritating to the mucous lining, from which it ab-

stracts water just as a piece of candy held in the cheek causes it to "pucker." Hence the best place for sweet food is at the end of a meal, when it will be diluted, so to speak, by the food already consumed, and when it will not come directly into contact with the stomach wall.

Sugar taken in dilute form, as in sweet fruits, or as a sweetener for the juice of acid fruits like lemon and grapefruit, is not irritating to the stomach, and should be quickly digested and absorbed. For those who engage in severe muscular activity, as athletes, or very active older boys and girls, some sugar taken in this way may be beneficial, especially if the intervals between meals are long.

As commonly used, honey and table syrups are a menace to digestion; i. e., taken freely with butter over hot biscuits, griddle-cakes, waffles, and the like, such a compound offers every opportunity for irritation of the digestive tract. It is hard to find a place for such foods in a dietetically well-managed family, save in the making of plain hard candies to take the place of soft, rich commercial confectionery. To eat a piece of such candy at the end of a meal is better than deluging food with syrup.

Molasses, carrying significant amounts of calcium, may be chosen as a sweet for growing children in preference to cane sugar or syrups with some advantage, if the amount of milk which can be obtained is not ideal; although it must be remembered that a tablespoonful and a half of molasses will yield only about the same amount of calcium as one-third of a cup of carrots diced in half-inch cubes. The iron in molasses

is high enough to deserve investigation as to its efficiency in nutrition. Hard molasses cookies, especially when made with whole wheat flour or with part of the wheat flour replaced by rolled oats, would seem to be an excellent sweet for children if used in moderation at the end of a meal.

Summary

Fats and sugars are primarily sources of fuel. Milk fat, whether cream or butter, is rich in vitamin A and on this account is of higher value than other food fats. Fat adds to the palatability of food and extends the range of culinary products greatly. It tends to retard digestion somewhat, giving a feeling of satisfaction after eating, but if used in excess, may delay digestion too much.

Sugars and other sweets owe their place in the diet to the popularity of their flavor. Contributing calories only, sugar can be replaced except as regards flavor and the part it plays in various culinary operations. Wise use implies great moderation as to quantity and care as to the time of eating sweets. Corn syrup and cane sugar yield calories only, but pure molasses is a concentrated vegetable juice, rich in sugar and also in calcium and iron.

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CHAPTER XII

THE CONSTRUCTION OF AN ADEQUATE DIET

Many factors enter into the food problem as it appears in everyday life. In the same household there are generally people of different food requirements. The baby cannot be fed like the five-year old, nor the five-year old like the high school belle, nor she like her football-playing brother. The dainty fare which best suits the school teacher is held in scorn by the farm laborer whose energy needs are twice as high. To use the same food resources for all and make adjustments which assure each a palatable, digestible and well-balanced diet calls for knowledge and skill in the apportionment of the various items on the menu.

But this is not all. There are other problems arising from the environment. Eating is a social matter. When the family is away for the day, the housemother may be quite content with a luncheon of bread and milk in the kitchen, but when the group returns she feels impelled to put on the dinner table a more imposing array of foods, for dining is a social function important to the higher life of the circle and there is a laudable desire to make the food worthy of the occasion. Furthermore, friends are entertained with food. Seldom is the guest allowed to depart without the hospitable offer of something to eat, not because he needs nourishment, but because this is a form of enter-

tainment held in high esteem. In apportioning the family food-money one has to consider in addition to the cost of actual nourishment how much must be added to meet the social ideals of the family itself, and how much for the entertainment of friends according to the standards of the community.

It is not within the scope of this chapter to deal with the broader social aspects of the food problem. The aim is rather to show how one may use knowledge of body requirements for the various dietary essentials and of the nutritive properties of common food materials to formulate a workable scheme for daily living; steering clear of the Scylla of perpetual calculation or worry and at the same time avoiding the Charybdis of eating according to the whim of the moment regardless of future welfare. Every person should have a simple program which shall take care of routine food needs systematically and effectively. To show how such programs may be formulated and tested is the main object of this chapter.

The analogy between building a diet and building a house is remarkably close. "Specifications" must be furnished by one who understands the whole building process. The man who has money enough goes to an architect and puts the whole matter in his hands. A special plan is made to meet his individual needs. So a man whose life depends upon a diet containing a specified number of grams of protein, fat, and carbohydrate for every meal, with no margin for mistakes or indiscretions, is fortunate if he can put his case into the hands of a professional dietitian who will assume responsibility for all details.

But this specialized service is too costly for the majority. Another way to get a house is to "shop around" for plans of various sorts made by good architects for books or magazines. These can be bought with full specifications at a nominal cost; and if one can be found approximating the builder's ideal it will be far better than an untrained person's plan. Similarly, one may ask a dietitian to make a set of menus and quantitative specifications for a diet to be followed day by day by the person or group for whom it is planned. An institution may have sets of such plans for various seasons of the year, each repeating every three or four weeks. The chief objection is the danger of too great monotony and too little adjustment to individual needs.

There is still a third way of getting a house. Certain firms supply units already built and easily fitted together and it is possible to select the ones which make the sort of house the buyer wishes. By choosing as many wall units as needed for a house of the desired size, the main outline is determined. One may then pick out any one of several styles of doors and windows, of porches and ells, of dormers for the roof, and assemble them according to his taste. The final result may not be as elegant as if each detail had had individual attention, but the dwelling can be very serviceable and far more artistic than anything an ordinary person would produce by starting with raw materials and evolving his own plan.

We build a diet by this third plan. We assemble foods as we would units of a house. We do not buy calories, grams of protein, iron, etc.; we buy meat

and potatoes, apples and eggs, which resemble the ells, porches, dormers, etc., of the ready-to-assemble house. These "units" have been described in Chapter XI. With a little study of their characteristics they can be fitted together to make a satisfactory whole, that is, an adequate diet for healthy individuals under ordinary living conditions.

Section I

A WELL-BALANCED DIET FOR A HEALTHY ADULT

We have said in Chapter XI that the foods from the cereal grains are primarily valuable as sources of energy, and secondarily as sources of protein. They are the most economical part of the diet, and the amount used depends largely upon the amount of money available for food. As much as one-half of the total calories of an adult man may be secured from this group of foods, but if over one-third of the total comes from this group, emphasis should be placed on the use of the grains with the bran and germ retained, since otherwise the burden of furnishing minerals and vitamins and laxative substances will fall too heavily on the rest of the diet.

Milk has been shown to be a great protector of the diet at almost every point; of unique importance for calcium, phosphorus, and other mineral elements, and for vitamins A and B. Even in the adult diet, therefore, a liberal amount of milk should be included at all times. At least a pint a day is a good rule, with increase to a quart as optional but desirable. This means a minimum of about 12 per cent of the total

calories of the diet from milk and a maximum of approximately 20 per cent according to the fuel value of the diet; 12 per cent of 3,000 calories would be nearly a pint, but it would take 18 per cent of 2,000 calories to get this amount.

Vegetables and fruits deserve a definite place in the diet because of the mineral salts and vitamins which they can furnish, and also because of their laxative properties. Green vegetables, carrots, tomatoes, and citrus fruits are particularly valuable, and should be used frequently. At least 10 per cent of the total calories should come from an assortment of fruits and vegetables and, unless cost is prohibitive, this group may well contribute from 15 to 20 per cent of the total calories.

Fats and oils, whose value for flavor and "staying power" as well as their high number of calories per pound makes them important in a well-balanced diet, may contribute from 10 to 20 per cent of the total calories. When other sources of vitamin A are limited, it is desirable that much of the fat be butter, but it is not wise to purchase butter to the exclusion of milk and green vegetables.

Sugars, while adding much to the palatability of the diet contribute fuel only and must not constitute a high proportion of the total calories or there will be danger of shortage of ash constituents and vitamins; and also of digestive disturbances. From 10 to 12 per cent of the total calories from sugar is usually satisfactory for an adult dietary.

The amount of eggs, meat, and other flesh foods to be used is determined partly by their nutritive value,

partly by their flavor and ease of preparation for the table, and partly by cost. As has already been shown in Chapter XI, meats are relatively expensive in comparison with their nutritive return. To get a good diet at low cost, it is best to increase the milk and decrease the meat. Eggs give a higher nutritive return than meat, and it is desirable that part of the calories allotted to this group come from eggs. Ordinarily the group allotment should not exceed 15 per cent of the total calories, and in very economical dietaries it will be less than 10 per cent.

A good diet at moderate cost can be readily constructed, using the following plan for the general distribution of calories:

I.	Foods from the cereal grains (including bread, crackers, macaroni, rice, etc., as well as breakfast foods)	30%
II.	Milk	13%
III.	Vegetables and fruits of at least three kinds	15%
IV.	Fats and oils (such as butter, cream, oil, suet, bacon, etc.)	17%
V.	Sugars and foods very rich in sugar (such as jellies and jams)	10%
VI.	Eggs, cheese, meat and other flesh foods	15%
	Total	100%

Applying this plan to a particular case, we may take for example a man of average weight (70 kilograms or 154 pounds) leading a fairly active life as a civil engineer, and needing about 40 calories per kilogram per day or a total of 2,800 calories. A balanced diet for him would therefore be represented by 28 shares of energy and 30 shares each of protein, calcium, phosphorus, and iron, foods being selected also with regard to a supply of vitamins A, B, and C. Taking our 28 energy shares, we may allot them to the differ-

ent groups of food according to our plan for the distribution of calories in the diet as follows:

DISTRIBUTION OF CALORIES AND SHARES IN A DIET OF MODERATE COST

CLASS OF FOOD	PER CENT OF TOTAL CALORIES	SHARES PER DAY
I. Foods from cereal grains	30	8.4
II. Milk	13	3.6
III. Vegetables and fruits	15	4.2
IV. Fats and oils	17	4.8
V. Sugars, syrups, preserves, etc.	10	2.8
VI. Eggs, cheese, meat and other flesh foods	15	4.2
Total	100	28.0

It will be no difficult task with this plan in hand to select foods for a day's menu, in the following manner:

SELECTION OF FOOD MATERIALS FOR A MODERATELY PRICED DIET

CLASS OF FOOD	SHARES REQUIRED	FOODS TO YIELD SHARES REQUIRED	MEASURE OF FOOD	NUMBER OF SHARES
I. Foods from cereal grains	8.4	Rolled oats (cooked)	1¾ cups	1.8
		Bread, white	8 half-inch slices 3×3½ inches	4.0
		Rolls	2 rolls	2.0
		Flour	2 scant tbsp.	0.6
II. Milk	3.6	Whole milk	2⅙ cups	3.6
III. Vegetables and fruits	4.2	Oranges	1 medium	0.8
		Apples	1 medium	0.8
		Potatoes	2 medium	2.0
		Tomatoes	½ cup	0.3
		Lettuce	½ head	0.3
IV. Fats and oils	4.8	Butter	4 tbsp.	4.3
		Olive oil	½ tbsp.	0.5
V. Sugars and syrups, preserves, etc.	2.8	Cane sugar	5⅓ tbsp.	2.8
VI. Eggs, cheese, meats and other flesh foods	4.2	Lean beef (cooked)	2 oz.	2.0
		Ham, lean	1 oz.	1.0
		Eggs	1½ eggs	1.2

Whether this selection of foods will make a well-balanced diet can now be tested by a little calculation. Taking the above list of foods and referring to the tables in the Appendix, we can find the contribution to the diet of each item as shown below:

A Moderately Priced Dietary

	Shares Contributed to the Diet				
Food Materials	Calories	Protein	Calcium	Phosphorus	Iron
Rolled oats	1.8	3.0	1.3	4.0	3.5
Bread and rolls	6.0	8.4	2.9	4.8	4.2
Flour, white	0.6	0.8	0.2	0.4	0.3
Milk, whole	3.6	6.8	27.2	11.0	2.5
Oranges	0.8	0.5	3.1	0.7	0.6
Apples	0.8	0.2	0.4	0.4	0.8
Potatoes	2.0	2.1	1.4	3.1	6.2
Tomatoes	0.3	0.5	0.7	0.8	1.1
Lettuce	0.3	0.7	2.9	1.5	2.3
Butter	4.3	0.2	0.4	0.2	0.2
Olive oil	0.5	0.0	0.0	0.0	0.0
Sugar	2.8	0.0	0.0	0.0	0.0
Beef, lean round	2.0	10.9	0.7	6.6	6.2
Ham, lean	1.0	3.0	0.2	2.0	2.2
Eggs	1.2	4.3	2.4	3.3	4.9
Total	28.0	41.4	43.8	38.8	35.0
Standard	28.0	30.0	30.0	30.0	30.0

By comparison of these totals with our standard we see that our selection of foods has given us ample protection at every point with regard to which calculations have been made. The contributions of the different groups are also interesting in view of the part which we expect each to play—the cereals mainly sources of energy, milk the chief source of calcium, the fruits and vegetables large contributors to the mineral elements and vitamins B and C.

Contributions from Different Food Groups

Class of Food	Shares Contributed				
	Calories	Protein	Calcium	Phosphorus	Iron
I. Foods from cereal grains	8.4	12.2	4.4	9.2	8.0
II. Milk	3.6	6.8	27.2	11.0	2.5
III. Vegetables and fruits	4.2	4.0	8.5	6.5	11.0
IV. Fats and oils	4.8	0.2	0.4	0.2	0.2
V. Sugar	2.8	0.0	0.0	0.0	0.0
VI. Eggs and meat	4.2	18.2	3.3	11.3	13.3
Total	28.0	41.4	43.8	38.2	35.0

The cereals contribute 29 per cent of the protein, the milk 60 per cent of the calcium, the fruits and vegetables nearly 30 per cent of the iron. The significant sources of vitamins are shown below:

Chief Sources of Vitamins

	Vitamin A	Vitamin B	Vitamin C
Rolled oats	–	++	–
Milk	+++	++	+?
Oranges	+	++	+++
Apples	+	+	++
Potatoes (boiled)	+	++	++
Tomatoes	++	++	+++
Lettuce	+	++	+++
Butter	+++	–	–
Eggs	+++	+	–?

There is every reason to believe that this diet is adequate in vitamins. The man for whom it is proposed will be most interested probably in knowing whether this selection of food "on principle" will make him an acceptable series of meals for the day. There are many possible combinations of any such assort-

ment of foods, but the following shows what can be done with the present selection:

A Day's Menu for a Moderately Priced Diet

Breakfast: Orange
Rolled oats, $1^3/_4$ cups; milk, 1 cup; sugar, 1 tbsp.
Toast (3 slices bread); butter, 1 tbsp.
Coffee; top milk, 2 tbsp.; sugar, 1 tbsp.

Luncheon: Broiled ham
Creamed potatoes with 1 hard boiled egg, (using flour, ¼ cup milk and 1 tbsp. butter)
Bread, 3 slices; butter, 1 tbsp.
Apple Betty (using the apple, 1 slice bread, 2 tbsp. sugar, and ½ tsp. butter and serving with $^1/_3$ cup milk)

Dinner: Round steak
Baked potato; butter, 1 tbsp.
Scalloped tomatoes (using 1 slice bread, 1 tsp. sugar and ½ tsp. butter)
Lettuce and French dressing (using the olive oil)
Rolls, 2
Bread pudding (using ½ cup milk, 1 slice bread, ½ egg, and 1 tbsp. sugar)

It must never be forgotten that the administration of a diet is quite as important as the plan upon which it is built. Just as the work of the architect is only begun when the plans are drawn and must continue until he has accomplished the greater task of finding the materials and the workmen to translate his paper house into a worthy edifice, so the dietitian must select foods with reference to good quality and fair price, must see that they are cooked so that their nutritive values are conserved or enhanced and not depreciated, and must combine them into meals which are satisfying and wholesome. Furthermore, these meals must be served with regularity from day to day, so that the human machine may run smoothly, without

wrench or strain so far as food is concerned. For a fuller discussion of the care of the digestive mechanism and adjustment to various problems related to feeding adult men and women the reader is referred to *Feeding the Family*. The following suggestions for the making of a good menu are taken from the *Laboratory Handbook for Dietetics*, 2d edition, page 76:

"1. Conceive of the whole day as the unit, rather than the individual meal.

"2. Endeavor to distribute the protein, fat, and carbohydrate through the day, so that no meal will have a striking preponderance of one kind of foodstuff.

"For example, meat served with macaroni and cheese concentrates the protein in one meal, potatoes with rice concentrate the starch, and fried potatoes and pie concentrate the fat.

"3. With the exception of a few such staples as bread, butter, and milk, try to avoid serving any food in the same form twice in the same day and serve it preferably only once in any form.

"4. Try to avoid serving any food which gives character to a dish twice in the same meal, even in different forms. Do not, for instance, select tomato soup and tomato salad for the same meal.

"5. At each meal, seek contrasts between successive courses, a bland course being followed by a more highly flavored course, and vice versa, to give a pleasing rhythm.

"6. In each course endeavor to have harmonious combinations, as to flavor, color, form, and texture.

"7. As the number of courses increases, decrease the number of dishes and size of the servings in each."

For an adequate diet for an adult at minimum cost, cereal foods must be made as appetizing as possible, and must be made the carriers not only of calories and considerable protein, but also of iron. Consequently the major portion of the cereal foods should be from the grain without removal of the bran nor the germ. A plan for the distribution of calories in an adult dietary of minimum cost is given below, and also for comparison a plan for one which is rather expensive owing to the small dependence put upon the grain foods, and the large proportion of fruits and vegetables.

Distribution of Calories in Diets of Low and High Cost

Class of Food	Low Cost *Percentage of Total Calories*	High Cost *Percentage of Total Calories*
I. Foods from cereal grains (including bread, crackers, macaroni, rice, etc., as well as breakfast cereals	40	20
II. Milk	18	16
III. Vegetables and fruits	12	20
IV. Fats and oils	12	18
V. Sugars, syrups, etc.	10	10
VI. Eggs, cheese, meat and other flesh foods	8	16
Total	100	100

The man doing hard physical labor is generally the one who must consider most carefully the cost of his calories, since he needs so many of them. Instead of applying the above plan to a day's ration for a professional man with a moderate energy requirement, we may better apply it to a carpenter needing perhaps 30 energy shares per day, as well as 30 shares of protein, calcium, phosphorus, and iron, and just as many vitamins as he would if less active.

Expressed in shares our distribution of calories will now be:

Distribution of Calories in a Low-Cost Dietary

Class of Food	Percentage of Total Calories	Shares Per Day
I. Foods from cereal grains	40	12.0
II. Milk	18	5.4
III. Vegetables and fruits	12	3.6
IV. Fats and oils	12	3.6
V. Sugars, syrups, etc.	10	3.0
VI. Eggs, cheese, meat, and other flesh foods	8	2.4
Total	100	30.0

Selection of Food Materials for a Low-Priced Diet

Class of Food	Shares Required	Food to Yield Shares Required	Measure of Food	Number of Shares
I. Foods from cereal grains	12.0	Bread, graham	¾ lb.	9.0
		Farina, (cooked)	1½ cups	3.0
II. Milk	5.4	Milk, whole	3 cups	5.4
III. Vegetables and fruit	3.6	Beans, navy	1/6 cup	1.0
		Tomatoes, canned	1 cup	0.6
		Potatoes	1 large	1.6
		Cabbage, shredded	2 cups	0.4
IV. Fats and oils	3.6	Pork fat	1 tbsp.	1.0
		Butter	2 tbsp.	2.0
		Beef fat	½ tbsp.	0.6
V. Sugars, syrups, etc.	3.0	Molasses	1½ tbsp.	1.0
		Cane sugar	2 tbsp.	2.0
VI. Eggs, cheese, etc.	2.4	Cheese, American	1 1/8 in. cube	1.0
		Beef, rump	2½ oz.	1.4
Total				30.0

It will be interesting to test this dietary as we did the former one to see whether it is adequate in protein, ash constituents, and vitamins.

A Low-Priced Dietary

Food Materials	Shares Contributed to the Diet				
	Calories	Protein	Calcium	Phosphorus	Iron
Bread, graham	9.0	12.3	7.8	17.1	17.2
Farina, light	3.0	3.7	0.8	2.4	1.3
Milk, whole	5.4	10.3	40.8	16.5	3.8
Beans, navy, dried	1.0	2.6	2.0	3.1	4.1
Tomatoes	0.6	0.9	1.3	1.5	2.1
Potatoes	1.6	1.7	1.1	2.5	5.0
Cabbage	0.4	0.8	2.5	0.8	2.8
Pork fat	1.0	0.0	0.0	0.0	0.0
Butter	2.0	0.1	0.2	0.1	0.1
Beef fat	0.6	0.0	0.0	0.0	0.0
Molasses, cane	1.0	0.3	3.2	0.3	5.1
Cane sugar	2.0	0.0	0.0	0.0	0.0
Cheese, American	1.0	2.6	9.2	3.5	0.6
Beef, rump	1.4	7.6	0.5	4.6	4.3
Total	30.0	42.9	69.4	52.4	46.4
Standard	30.0	30.0	30.0	30.0	30.0

It will be noted that by the selection of whole wheat bread, the use of navy beans whose nutritive value is high in proportion to cost and the inclusion of a liberal supply of milk, this diet is better protected at every point indicated above than is the more expensive one on page 381.

The sources of vitamins are indicated below:

Chief Sources of Vitamins

	Vitamin A	Vitamin B	Vitamin C
Graham bread	+	++	−
Milk	+++	++	+
Beans, navy	+	+++	?
Tomatoes	++	++	+++
Potatoes (boiled)	+	++	++
Cabbage (raw)	+	++	+++
Cheese	++	− ?	?
Butter	+++	−	−

The larger amount of milk and the cheese help to safeguard this diet as regards vitamin A. The use of tomatoes instead of some vegetable less rich in A is for the same purpose, and might have to be repeated many times unless there were available other vegetables rich in A (such as spinach or other greens). There are not as many foods yielding vitamin C, hence the desirability of using the cabbage raw, instead of destroying much if not all of the vitamin by cooking. The use of tomatoes and potatoes, both good sources of C, gives assurance of a sufficient supply. In using other vegetables, where the number is limited, care should be taken to have one other good source of vitamin C besides potatoes.

A menu illustrating the practical use of this more limited assortment of food materials is perforce simpler than one for which a larger number of kinds of food has been used, and bread is the chief staple in every meal.

A Day's Menu for a Low-priced Diet

Breakfast:	Farina with 1½ cups milk and 1 tbsp. sugar Graham bread, ¼ lb. with molasses and coffee
Luncheon:	Baked beans with pork fat Graham bread, ¼ lb. Cheese Milk, ½ cup in coffee
Dinner:	Beef stew with potato, tomato, and beef fat Raw cabbage Graham bread, ¼ lb.

Section 2

WELL-BALANCED DIETS FOR GROWING CHILDREN

During the last half century there have been real gains in prolonging human life and preventing ill

health. In New York City in 1875 the death rate was 28.3 per 1,000; by 1925 it had been reduced to 11.5. The average life span in the city in 1880 was about 40 years; it is now 55 or 56 years. This improvement has been brought about by a great extension of the application of modern scientific knowledge to the public health problem. Sanitary science has conquered many infectious diseases and protected food and water supplies; the recent rapid growth of the science of nutrition has revealed the full measure of control which diet exercises over life and health. "We have learned," says Dr. Charles H. Mayo, "that the growth of microbes resembles the growth of seed and must have a soil adapted to it, which may have to do with age, degeneration, inherited traits, and changes due to food. Thus in the last five years we have paid more attention to dietetics than ever before, and have come to believe that there is a great deal of truth in the statement that a man digs his grave with his teeth."

We have as yet no impressive mass of data to prove that improvements in diet are contributing directly to the prevention of sickness and the extension of efficient living. It will take wide adoption of the modern principles of nutrition and carefully controlled observations covering many years to make an impressive demonstration of the improvement in human life which can be achieved by a good dietary consistently eaten from birth to old age. But we do have the conquest of goiter and cretinism, of beriberi and pellagra, of scurvy and rickets, wherever these have been scourges, as evidence that an adequate diet is a real factor in public health; and from the nutrition lab-

oratory we have abundant proof that starting with a diet already good, we may by making it still better, produce in successive generations of animals living in exactly the same environment, a distinctly higher degree of health and vigor.

No child ever had so good a chance of being well-born as one entering the world at the beginning of the second quarter of the twentieth century. Down to the nineteenth century babies seemed born to die, for at least a quarter of them failed to survive the perilous first year. But to-day the infant mortality in most American communities has been reduced to about 7 per cent, according to Dublin,[1] who believes that in the near future two-thirds of these deaths will be prevented. Now that sanitary science has conquered many children's diseases and made safe the food supply, the application of our present knowledge of nutrition is more important than ever, to insure to these "saved" babies normal growth from birth to maturity and attainment of such physical vigor as shall make their working years long and fruitful. "Where vitality exists," says Bertrand Russell, "there is pleasure in feeling alive. It makes it easy to take an interest in whatever occurs, and thus promotes objectivity, which is an essential of sanity. Vitality promotes interest in the outside world; it also promotes the power of hard work."

The Pre-School Child

The period of infancy presents a highly specialized feeding problem and we shall temporarily pass over

[1] Dublin, L. I. "The Economics of World Health." *Harper's Magazine*, November, 1926.

this, returning to it after discussing the dietary needs of the little child who has passed the period of transition from mother's milk to an independent dietary, but is still in the home and fed apart from the family group. In the United States where the food supply is so well protected and knowledge of infant care is free for the asking,[1] a child becomes independent of his mother's milk usually towards the end of his first year, but he is still in the period when growth is very rapid and sensitiveness of the digestive tract great. His food is a tremendously significant factor in his progress at this time, when his only business in life is to grow. The quantitative food requirements for children of various ages have already been discussed under each type of dietary essential. It remains now to see how such knowledge is applied to the everyday feeding problem.

A year-old baby of average size will require from 900 to 1,100 calories per day, the precise amount varying according to body weight and amount of activity. The large, vigorous, active child will require more total food than the small, delicate, less strenuous one. The energy requirement from day to day cannot be foretold exactly; the regular weighing of the child week by week, and comparison of his rate of progress with our best normal averages is the best criterion of the adequacy of the food supply. But an approximation of the number of calories required is most useful in planning a good dietary, and such increases or decreases as may be necessary are readily made.

[1] Three excellent pamphlets by Mrs. Max West, *Prenatal Care*, *Infant Care*, and *Child Care* are free for the asking from the Children's Bureau, United States Department of the Interior, Washington, D. C.

Every calorie must be chosen with regard to the growth-promoting substances it can furnish and its effect upon the digestive tract. Hence it will be desirable to discuss briefly the kinds of food most appropriate for the pre-school child's diet before considering in detail their quantitative relationships. The evidence that the best foundation for the diet is a quart of fresh, clean, cow's milk [1] has been summarized in Chapter XI. This amount of milk will insure adequate protein, calcium, phosphorus, vitamin A, an assortment of other essential mineral elements and much vitamin B, all in a form specially easy to digest. For vitamin C it is not wise to depend upon the variable supply in milk, but to use some outstanding source known to digest well, such as orange juice or tomato juice, making a small quantity a regular part of the diet. Two tablespoonfuls per day of either orange or tomato juice are ample as a rule.

A small quantity of egg yolk (about one teaspoonful) is desirable, for its value in hemoglobin formation and its many other growth-promoting qualities.[2]

A little green vegetable pulp is also to be included, as a further source of iron and other mineral and organic elements, and for its laxative properties. This should be quickly cooked and put through a fine sieve and should not exceed in quantity 2 level tablespoonfuls, lest it lead to digestive disturbances, which are often insidious and must therefore be sedulously guarded against. Spinach, asparagus tips, and peas

[1] Whether pasteurized or not, it should be fresh and clean and unchanged by the growth of bacteria.

[2] Occasionally leads to digestive or skin disturbances; then it should be omitted. The white is more likely to be at fault than the yolk.

are very suitable, singly or in combination, and carrots, though not green, are also valuable.

Since the proportion of protein in cow's milk is too high for the best growth, a cereal food should be added, choosing preferably one which yields iron, such as rolled oats or a dark farina, cooking it very soft, and putting it through a sieve (except when the finely ground farina is used). This can be served regularly twice a day, from one-fourth to one-third of a cup of the cooked cereal in the morning and another similar portion for supper being usually sufficient. A small amount of baked potato is also a desirable food for this age, reinforcing the diet in regard to iron and vitamin C, and adding other mineral elements and vitamin B.

For the sake of stimulating the circulation in the gums and developing the chewing habit, some dry hard bread or toast is extremely important, and one or two small slices can be given at each of two meals. A little butter on the bread is permissible, but the ounce and a quarter of butter fat in the quart of whole milk makes much additional fat at this age undesirable. Generally a little prune pulp or apple pulp, put through a sieve and sweetened with the merest trace of sugar, for the sake of palatability, can be used without making the diet too laxative or too difficult to digest, but should be omitted if there is any doubt as to its good effect. There is over an ounce of sugar in the milk and that is plenty for a day.

The diet as outlined above may be used with little change throughout the second year. By the eighteenth month cereals may be given unstrained, provided they

have been cooked very soft. The milk to drink should always be warm. The quantity of bread may be increased, adding a third slice at the noonday meal. All the bread should be dry and hard. *It fails of its main purpose if soft.* The egg yolk may be increased to one yolk daily. The white is better reserved for the adult dietary. Vegetables should be cooked quickly till soft and put through a sieve or mashed fine. Those which do not lend themselves to such treatment should be deferred till the child is older. As an alternate to cereal for supper, vegetable pulp may be combined with milk in a cream soup and served with small squares of toasted bread. For a detailed food plan and dietary for a child eighteen months old, consult *Feeding the Family*, pages 142 and 143.

A good guide to a well-assorted dietary for the one-year-old child may be expressed in terms of the total calories, and will fall within the following limits:

Distribution of Calories for the Diets of Children One Year Old

Class of Food	Per Cent of Total Calories
I. Foods from the cereal grains (cereal jelly and bread)	10–20
II. Milk, whole	65–75
III. Vegetables and fruits (specially selected)	5–10
IV. Butter	1–3
V. Sugar	0–1
VI. Egg yolk	2–3

Taking for example an allowance for a day of 1,000 calories (or 10 shares) we may proceed to distribute them in the following fashion:

Distribution of Calories and Shares in a Diet for a One-year-old Child

Class of Food	Per Cent of Total Calories	Shares Per Day
I. Food from cereal grains	16.0	1.60
II. Milk	67.5	6.75
III. Vegetables and fruit	10.0	1.00
IV. Butter	3.0	0.30
V. Sugar	1.0	0.10
VI. Egg yolk	2.5	0.25
Total	100.00	10.00

Selecting from the foods which are regarded as best suited to a child of this age, we shall have some such list as this:

Selection of Food Materials for a One-year-old Child's Diet

Class of Food	Shares Required	Food to Yield Shares Required	Measure of Food	Number of Shares
I. Foods from cereal grains	1.60	Rolled oats (strained)	3/8 cup	0.60
		Bread, white	2 slices	1.00
II. Milk	6.75	Milk, whole	1 quart	6.75
III. Vegetables and fruits	1.00	Orange juice	2 tbsp.	0.15
		Pea pulp	2 tbsp.	0.15
		Potato	1/2 medium	0.50
		Prune pulp	1 tbsp.	0.20
IV. Butter	0.30	Butter	1 tsp.	0.30
V. Sugar	0.10	Sugar	2/3 tsp.	0.10
VI. Egg yolk	0.25	Egg yolk	1/2 yolk	0.25
Total				10.00

To see whether a diet planned in this way is really adequate or not we may calculate the contribution of each food item as shown on page 396.

The standard for a child expressed in shares must have relatively a higher number of calcium and phosphorus shares than energy shares to make the total calcium and phosphorus approximately 1 gram per child per day.

One share of calcium is 0.023 gram ($^1/_{30}$ of an adult man's daily requirement), and 10 shares would be only 0.23 gram, which is insufficient for a child. To get a full gram we shall need $\frac{1.0}{0.023}$, or 43 shares. Similarly, to get one gram of phosphorus, we shall need $\frac{1.0}{0.044}$, or 23 shares. Comparing our diet with this standard we find that it is adequate at every point calculated, but is not as well protected in regard to iron as the other items. It would

A Dietary for a One-year-old Child

Food Materials	Calories	Shares Contributed to the Diet			
		Protein	Calcium	Phosphorus	Iron
Rolled oats	0.60	1.0	0.4	1.4	1.2
Bread, white	1.00	1.4	0.5	0.8	0.7
Milk, whole	6.75	12.8	51.0	20.6	4.7
Orange juice	0.15	0.1	0.4	0.1	0.1
Pea pulp	0.15	0.4	0.2	0.4	0.5
Potato	0.50	0.5	0.4	0.8	1.6
Prune pulp	0.20	0.1	0.2	0.2	0.4
Butter	0.30	0.0	0.0	0.0	0.0
Sugar	0.10	0.0	0.0	0.0	0.0
Egg yolk	0.25	0.4	0.4	0.7	1.2
Total	10.00	16.7	53.5	25.0	10.4
Standard	10.00	10.0	43.0	23.0	10.0

seem advisable, therefore, to substitute a fine whole wheat bread for part if not all of the white bread. It should be noted, however, that over half the iron comes from milk, and will be most efficiently used especially when fed in conjunction with green vegetables.

That the diet is adequate in vitamins A, B, and C is guaranteed by the milk and orange juice, with a margin of safety furnished by the egg yolk, pea pulp, and potato. The addition of a small amount of cod-liver oil in the winter furnishes vitamin D to help in bone growth when the ultra-violet light of the sun is scanty,

and also adds vitamin A which can be stored if not immediately needed.

The daily program at this age involves four meals

(*Courtesy of Captain Donald B. MacMillan and the American Museum Journal*)

FIG. 84.—Me-gis-s'oo and Shoo-e-ging-wah are playing with their pet dogs in the July sun at Etah. In the summer months, on days when the wind is not too strong, Eskimo mothers give their babies sun baths on bear- or deerskins stretched on the ground. Needless to say the little people like it, and continue to like it until they are quite big boys and girls.

a day, the first at some definite time between 6 and 7:30 A. M. according to the habits of the family; the

second at 10 or 10:30 (at least three or three and one-half hours after the first); the third at 2 or 2:30 P. M. after the midday nap; the fourth at 5, 5:30, or 6 P. M., depending upon the sleeping schedule. Fourteen hours should be allowed for the night's sleep and no little child should be up after 7 P. M.

The food may be distributed through the day as follows:

A Day's Menu for a One-year-old Child

7:00 A. M.	Warm milk to drink, 1 cup
9:00 A. M.	Orange juice, 2 tbsp. (This may be diluted with an equal amount of water and in the winter 2 tsp. of cod-liver oil added)
10:00 A. M.	Cereal jelly, 2½ tbsp. with ¼ cup of warm milk over it Warm milk to drink, ¾ cup Bread, 1 slice, stale or toasted, with ½ tsp. butter
2:00 P. M.	Potato, baked, ½ medium, with 1 tbsp. milk to moisten Pea pulp, 2 tbsp. with a little milk to moisten Egg yolk, ½ mixed with the potato or with bread crumbs Prune pulp, 1 tbsp. Warm milk to drink, ¾ cup
5:30 P. M.	Cereal jelly, 2½ tbsp. with ¼ cup warm milk Bread, 1 slice, stale or toasted, with ½ tsp. butter Warm milk to drink, 1 cup

The little child's diet must be administered with scrupulous care. Not only is it ministering to immediate needs for growth, but it is also favorably or unfavorably affecting the digestive tract and eating habits.

Meals must be regular. This is easy to say but very difficult to accomplish, and a rule too often broken by those who have little children in charge. Waiting beyond the regular meal time is likely to bring many undesirable reactions such as irritability, fatigue, loss of appetite, or hurried eating.

The foods which comprise the simple menu should be of the best quality, carefully seasoned and offered

in a way to commend them to the child. By word and action, respect and enthusiasm for the foods which are desirable for his welfare should be imparted. Always the constructive idea that each food is playing its part in building a healthy, happy child should be kept uppermost.

No child should be pitied because of his simple, wholesome diet. No diet is better than that which adequately supports the rapid growth of the early years, and there should be no suggestion of any other possibility than eating it cheerfully at the proper time. Food for the young child is not an amusement but serious business upon which his whole progress in life largely depends. It is not to be expected that all foods will be equally well received at first. New foods are new lessons. They should not be made too difficult. By giving very small portions at first a ready acceptance of many foods is best built up.

To allow no food between meals should be an absolute rule. Nothing is more ruinous to good appetite, good digestion, and good discipline than food at improper times.

Sweets should be rigorously withheld. They pervert the appetite, and are likely to disturb digestion. There is plenty of sugar in the milk. Only what is absolutely necessary to make apple sauce, junket, or other very simple milk puddings palatable, should be used.

Nursery School and Kindergarten Children

Imitation plays a large part in the little child's life, and it is much easier for him to eat what is given him when others are doing the same. A few children now

have the opportunity of attending nursery schools and in the future undoubtedly more will have a similar privilege. For such children the pre-school period is shortened to a year or so, as sometimes the nursery school admits children under two years of age, though the usual age range is from two to four or five years.

When the children arrive in the morning they should at least have a drink of water. If they have breakfast early, and it fits well with the home schedule, they may instead of water have two tablespoonfuls of orange juice diluted with as much water; and since children use up their blood-sugar fast, the addition of not more than one teaspoonful of corn syrup or malt food (glucose and dextrin or maltose, never sucrose) should help them to go through the morning with less fatigue. This applies particularly to children under four years of age, but is not disadvantageous for any child of nursery school age. Where the winter season is cloudy, the addition of at least one teaspoonful of cod-liver oil to the morning feeding is an additional safeguard, giving vitamin A as well as vitamin D. If this is given regularly at home, it may not be needed at the school. There must be at all times the closest coördination between the home and school programs.

The Mid-day Meal at the Nursery School

The noonday meal, taken at the school, affords an unusual opportunity for training in good eating habits. The food must be selected with the greatest care, since the school's responsibility for the well-being of the children is heavy. It must be apportioned as carefully as possible according to the requirements of the

individual child, and yet the group spirit must be preserved. A dietitian expert in the training of children as well as in nutrition is essential to the highest success and should have constant oversight during the meal. The ease with which children two to four years old (and sometimes even younger) can adapt themselves to the food régime of the school is abundant proof of the power of *esprit de corps.* Sitting at their little tables with their teachers they eat together in the happiest fashion. Now and then some food seems more of a task than a wee one can accomplish, but helped along by an encouraging word, or perhaps a lift with the spoon, the goal of a clean plate is won; or a wise teacher quietly lightens the task if in her judgment it is too great for the moment. It is highly important that any one who supervises the children's meals have training in nutrition as well as in other phases of child care, so that the child's immediate food needs and his education may be properly related to each other.

Day by day the nursery menu must exemplify the best that is known in regard to child feeding. It affords education for parents as well as children. A good program for the dinner will include:

(1) A baked potato or its equivalent creamed or mashed.

(2) A vegetable rich in mineral salts and vitamins, cooked soft and mashed fine. Children of this age can be educated to a considerable range of vegetables, and while a great variety is not essential to their immediate growth, carrots, spinach and peas being all that one really would need, it is for the convenience

of the home and the future ability of the child to adjust himself easily to all wholesome food that his range should be gradually widened.

(3) The yolk of an egg. While it is desirable to serve this without the white, economic considerations hardly justify a school in rejecting the white of every egg. Hence a daily average per child of from one-half to a whole egg seems about the best that can be done under ordinary conditions. The egg can easily be given scrambled or creamed; it may be mixed with the vegetable or potato, or made into a simple dessert such as baked custard, or cornstarch, or bread pudding. Occasionally it may be omitted so that egg may be included in the home menu. Veal liver, steamed and put through a food chopper, may be creamed and served with the vegetables. Creamed fish such as halibut, or a little chopped lean beef may also serve as an egg substitute now and then, not more than about half an ounce of any one of these being given to each child. With the exception of liver, meat is too poor in growth-promoting properties, and too stimulating to be given a place of any prominence in a child's diet. It must never be allowed to displace milk or vegetables.

(4) A full cup of milk of room temperature. This is managed more easily by the children if a small cup is used and refilled. The person in charge has to see to it that each child gets his full share.

(5) A regular portion of hard dry bread to chew. The quantity cannot be very large or it will take the children longer to get through with their meal than they can endure to sit, even in chairs adapted to their size. Half a slice of whole wheat bread thoroughly

toasted will serve the purpose very well. Other breads, untoasted, can be used to fill the quota of calories.

(6) For the sake of establishing the habit so desirable later on of eating a certain amount of fresh uncooked vegetable food, it is permissible to incorporate a very little minced raw vegetable into the diet at this age, using it as a sandwich filling. Carrots and lettuce lend themselves admirably to this use; a little of the carrot top can be chopped in with the carrot itself, and a very little raw apple with the lettuce. The sandwiches are well liked by young children, and in the light of modern knowledge of food values, are an improvement over bread and jelly, jam or honey. Such use of raw vegetables must not be interpreted as countenancing the indiscriminate use of raw vegetables or fruit at this period. Except as given above, neither is safe for young children. With the exception of orange juice or other mild fruit juice, fruit should generally be cooked, though thoroughly ripe bananas may be cut in small pieces and served with orange juice. The effects of even mild indigestion are insidious and should be most carefully guarded against.

Coöperation Between School and Home

The nursery school child may remain in school till the middle of the afternoon, in which case the interval between the early school dinner and the evening meal may be over five hours. If this is likely to be the case, the school schedule may include a light afternoon feeding, especially for children under three or four. From one-half to three-quarters of a cup of milk served with a plain hard whole wheat cracker makes a good

afternoon refreshment, if it does not interfere with the appetite for supper. Here again adjustment between home and nursery schedule is imperative. If the appetite for supper is interfered with, the afternoon feeding should be omitted or the size of portions decreased till an adjustment is secured.

If the child has only breakfast and supper at home, the nursery school must be responsible for at least 500 calories. In one nursery school graham crackers are always furnished with the dessert, giving not only extra calories for the children who need them, but also something more to chew.

With the child eating in two places, the best diet cannot be assured unless there is continued coöperation between the school and the home. By frequent conferences with the parents the dietitian must learn the home situation in detail and they together must arrange a plan which will insure a unified day's dietary for every child. Obviously, this will have to be built around the noonday meal at school, which must serve the whole group with only such modification for individual cases as comes from changes in quantities of food served, since it would be impossible to cook a different meal for each child.

The home breakfast should consist of a well-cooked cereal, served with milk, a cup of warm milk to drink, and from one to three slices of toast or zwieback or dry bread. When orange juice is given at the nursery school, not more than one or two tablespoonfuls should be given with the breakfast, and an equal amount of prune or apple pulp may well be substituted. Prunes are valuable where a more laxative diet is needed, and so are cereals made from whole grains.

A very good main dish for supper is a creamed vegetable soup with small squares of toasted bread (others are milk toast, or cereal and milk; or sometimes a baked potato with another vegetable cooked soft and well mashed), some bread spread lightly with butter and a cup of warm milk to drink.

There may be added, if the child sleeps well after it, a small serving of mild stewed fruit such as apple sauce, stewed pears, or baked banana. Sometimes a graham cracker or a plain hard molasses cooky will prove less disturbing at night.

The Kindergarten Child

The child who does not enter a nursery school at two or three may begin his school experience at the age of four or five in kindergarten. He will have less feeding at school than the nursery school child, but there will nevertheless be certain adjustments necessary when he starts on his school career. Breakfast may have to come earlier and dinner later, and a mid-morning school lunch become a practical necessity if he is not to be fagged out before reaching home at midday. The morning hours cannot be spent in the open sunshine, and plans must be made to secure a good sun bath every day that the sun shines. There is danger of hurrying breakfast and eating an insufficient quantity of food, hence the morning program must be arranged to allow for leisurely eating of the proper amount of breakfast and a bowel movement afterward—no mean achievement for a busy mother and a child sure to be slow when any one specially wants him to be quick!

The breakfast should continue to consist of orange juice or other fruit juice (stewed prunes or apple sauce occasionally if preferred), well-cooked cereal, toast or other hard bread, and from one to two cups of warm milk, part on the cereal and part to drink. Shredded wheat or zwieback with warm milk poured over it may be now and then used instead of oatmeal or dark farina. In either case the child has a warm wholesome breakfast. For the school lunch, milk as a rule is the most desirable food. The cupful taken then helps to distribute the day's quart advantageously, and the drinking of milk in school tends to reinforce the idea that milk is important. Furthermore, milk is easy to serve and easy to digest. A hard whole wheat or graham cracker will make it digest more quickly. Orange juice has also been used successfully for the mid-morning feeding. It should always be so timed that the interval between it and dinner is longer than the interval between it and breakfast—nearer nine o'clock than ten.

The dinner should come as soon after the school session as practicable and be the most substantial meal of the day. Such dinners as have been outlined for the nursery school children are suitable for kindergartners too.

The evening meal should frequently have as the main dish cereal, toast, or bread with milk, using perhaps rice or some other cereal not served for breakfast. Some of the ready-to-eat cereals with plenty of milk are excellent for supper. A creamed vegetable on toast may be served as an alternative to the cereal supper or a baked potato with some other vegetable.

A dessert of stewed fruit, custard, or junket may be supplemented by graham crackers or a plain hard cooky. If the milk is not used for the main dish it should be served as a beverage.

Good distributions for the calories in the kindergarten child's diet are shown below:

Distribution of Calories for Well-Balanced Diets of Children from Three to Five Years of Age

Class of Food	Per Cent of Total Calories for Each Age: Three Years	Four Years	Five Years	Range
I. Food from cereal grains (including bread)	22	23	24	20–25
II. Milk	55	50	45	45–55
III. Vegetables and fruit	13	14	15	10–18
IV. Butter	5	7	9	3–8
V. Sugar	1	2	3	0–5
VI. Egg yolk	4	4	4	3–6

How this plan works out in the case of the three-year-old is seen in the following table:

Selection of Food Materials for a Three-year-old Child's Diet

Class of Food	Per Cent of Total Calories	Shares Required	Food to Yield Shares Required	Measure of Food	Number of Shares
I. Food from cereal grains (including bread)	22	2.	Dark farina (cooked)	1 cup	1.20
			Bread, whole wheat	2 slices	1.25
			Flour	1 tbsp.	0.45
II. Milk	55	7.2	Milk	34 ounces	7.20
III. Vegetables and fruit	13	1.7	Carrots (cubes)	1/5 cup	0.25
			Orange juice	4 tbsp.	0.25
			Apple (small)	½ apple	0.35
			Potato (small)	1 potato	0.85
IV. Butter	5	0.7	Butter	2 tsp.	0.70
V. Sugar	1	0.1	Sugar	½ tsp.	0.10
VI. Egg yolk	4	0.5	Egg yolk	1 yolk	0.50
Total	100	13.1			13.10

If we desire to test this diet to see whether our distribution of calories and choice of foods has resulted in a well-balanced dietary we may make the following calculations:

A Dietary for a Three-year-old Child

Food Material	Shares Contributed to the Diet				
	Calories	Protein	Calcium	Phosphorus	Iron
Farina, dark	1.20	1.7	0.7	3.2	3.4
Bread, whole wheat	1.25	.0	0.4	1.6	1.5
Flour, white	0.45	0.6	0.1	0.3	0.2
Milk	7.20	13.7	54.4	22.0	5.0
Carrots	0.25	0.2	1.4	0.6	0.7
Orange juice	0.25	0.2	0.7	0.2	0.2
Apple	0.35	0.1	0.2	0.2	0.3
Potato	0.85	1.0	0.6	1.3	2.6
Butter	0.70	0.0	0.0	0.0	0.0
Sugar	0.10	0.0	0.0	0.0	0.0
Egg yolk	0.50	0.9	0.8	1.3	2.3
Total	13.10	20.4	59.3	30.7	16.2
Standard	13.00	13.0	43.0	23.0	13.0

Elementary School Children

How much is a child worth? It has been estimated that a baby born into a family whose total economic resources are $2,500 a year has a potential money value to society of $9,333. This is the amount which it would be necessary to put at interest at 3½ per cent to rear a child to age eighteen, and to realize finally a sum equivalent to his net earnings during his working years if he earn $2,500 a year. At age five the corresponding figure is $14,156.[1] These estimates are far below the real cost, since no account whatever is

[1] Dublin, L. I. "The Economics of World Health." *Harper's Magazine*, Vol. 153, pages 734–741 (1926).

taken of the cash value of the mother's services at any period.

No one would consider this large sum of money as indicating the full worth of a child. His presence in health and happiness gives values to life which are immeasurable. But putting a part in terms of hard cash may help us to realize a little better our responsibility for his well-being. The child leaving the kindergarten with an estimated economic worth of $14,000 will pass from the elementary school with this value increased at least 50 per cent provided he is in good health and has learned how to take care of himself. At present the foundation for adult health is not as securely laid as it ought to be, for a study of 500,000 life insurance policyholders reveals that 10,000 of this number must be counted as sick at any given time. Such a reckoning does not take account of the days when these people although at work are miserable and inefficient because of physical disability. Even a cold, which does not prevent most people from carrying through the day's routine, may change entirely the quality of work done.

By more attention to the health of the pre-school and kindergarten child, we can cut down many of the handicaps which to-day are found among elementary school children. Physical defects should have been as far as possible removed and good health habits already established when the six-year-old enters the primary school. But he cannot now be safely left to guide himself. He has covered only about one-fourth of his period of growth, and good habits are by no means fixed. Furthermore, he is just approaching the

years in which inculcation of the reasons for health habits and respect for the laws of hygiene should be a consistent part of his education, both at home and at school. "We strike at one of the roots of physical unfitness when we begin the teaching of food selection to all children, regardless of whether they appear to be undernourished or not. No immediate striking gain in weight is the objective of such teaching. What we want is to rear children who are intelligent as to the rôle which food plays in their lives, who are aware of their own responsibility in regard to food selection, and are imbued with a determination to make their daily food a factor contributing to health and not working against it, even though results cannot be measured from day to day nor from week to week—only from month to month or year to year. To this end they must have, (1) the habit of eating certain foods which in large measure insure a well-balanced diet, (2) sufficient knowledge of the part played in individual foods to make up for themselves suitable combinations for meals, (3) such knowledge of their own food requirements as will enable them to satisfy their needs at a table provided for persons with varying requirements, (4) such ideas of the relation of nutritive value to cost of food as will enable them to be thrifty in meeting their body needs." [1]

By the time a child is ready to enter the elementary school he should be eating a dietary in which milk, eggs, cereals, simply cooked vegetables in considerable variety, mildly acid fruits, mostly stewed save for

[1] Health Education Report of the Joint Committee on Health Problems in Education, page 39 (1924). For a further statement of the objectives in teaching food in the elementary school, see pages 39–41 of this report.

orange juice, hard dry bread and butter are the chief items in the diet. All foods should be cooked as simply as possible. A glass of milk at each meal and a cup used in soup or dessert will generally take care of the daily quart satisfactorily. No tea or coffee should be permitted, nor even strong cocoa. A very little cocoa may be used to flavor warm milk, but often a little malted milk or a powdered cereal beverage will serve for flavor quite as well.

Raw vegetables should be grated or finely cut and used in small quantities until the habit of thoroughly chewing them is established. They should be seasoned with a little mild fruit juice, not with the salad dressings commonly used by adults. Fat is best used as a spread for bread, rather than in cooking. Whole milk is better to use over cereals and puddings than cream. No soft cake should be permitted, but one or two graham crackers or plain hard cookies may be used at the end of a meal.

Training Children to Eat

Regularity and simplicity are the great watchwords for the diet of the elementary school child. More and more he will take an interest in his own food, and more and more opportunity will come to teach respect for all good food because of what it can accomplish for the body. Talk about personal likes and dislikes should be discouraged. The idea that one can get over distaste for food which one knows to be wholesome by repeated efforts to eat small portions should be substituted for any discussion of dislikes. Minor changes in the food often help the child in such an

endeavor. A little difference in appearance, flavor or texture may mean more than an adult is aware of. Grown-ups make many such adjustments for themselves at the table. Why do pepper and salt shakers appear there, save for this very purpose? "Some like it hot, some like it cold," and which way they have it may be immaterial. It is a wise parent that knows when not to insist! Spinach and potato together may be easier to eat than spinach alone. A little more salt may make the oatmeal seem like a different food. Remember Dickens' kitten pies—whatever the kind of meat, "it's flavorin' as does it!" Fair substitutes may often be allowed when they do not work injustice to any one else. If a child prefers shredded wheat to oatmeal may he not have it, since no work is involved in preparing it and the two foods are nutritionally interchangeable? Eventually, he should learn to eat both, but tastes and ideas change and if he is eating according to his own nutritional needs we should not at this time put too much emphasis on variety.

Any one responsible for feeding a child should be familiar with some of the striking effects of food upon health and growth such as have been referred to in the preceding chapters, and these should be used to put the choice of food upon a higher plane than mere fancy. The demonstration of the effect of food upon the growth and health of animal pets gives a real incentive to eat what one needs regardless of whether it seems most attractive at the moment, and no attitude is more valuable for future health.

In order to fit properly into the family routine every child should be expected to taste any food which it is

important for him to eat, every time it is served, but the quantity insisted upon should not be too large if it is difficult for him to take. Frequent repetition under favorable circumstances is much more likely to be successful than a forced overdose. Other habits are established only by patient repetition, and one should not expect food habits to be any exception. Desirable attitudes toward food may be cultivated by taking pains to prepare the child's mind in advance for any new food he is to have, instead of springing it upon him without any recommendation or at an unfavorable moment.

General Plan of Meals

The primary school child's energy needs are high but his digestive tract still needs to be carefully safeguarded. Breakfast must be ample, but very simple and not eaten too hurriedly. No child starts the day well who has not gone to bed early (before 7:30 P. M.) and had a full night's sleep. During the night he needs fresh cool air to give him a good appetite for breakfast. Fruit, a warm cereal with milk, milk to drink (not chilled) and toast to chew, make a breakfast adequate as to food value and easy to digest. The warm cereal dish may consist of a cooked cereal with cold milk, or a ready-to-eat cereal with warm milk. Care must be taken to have breakfast at the regular time on Saturdays and Sundays as well as school days, and also meals of the same general character. Every day is growing day for a child and whatever food program is important to-day is equally important tomorrow. By the age of six or seven, orange juice may give place to the

whole orange, prune pulp to whole stewed prunes, and apple sauce to raw apples or pears provided they are perfectly ripe. Other mild fresh fruits can also be used for breakfast in their season.

School conditions will now affect the time and character of the mid-day meal. In the rural district it will be eaten at the school. There should always be one hot dish available, since warm food promotes the circulation, relieves fatigue and makes the afternoon session easier. Cocoa made with milk or a nutritious milk and vegetable soup with bread and butter (or sandwich) and fruit will make a wholesome noonday meal. When the children can go home for dinner, a potato, another cooked vegetable, an egg, or a little meat, a small portion of some raw vegetable such as lettuce, tomatoes, cabbage, or carrots, a glass of milk to drink, and a simple dessert of stewed fruit or a milk pudding make a suitable meal. All the foods should be simply cooked, for the child must go back to school to use his brain, and a meal difficult to digest must not take all the blood away from his head. The delicate child will benefit from a short rest flat on his back before his dinner; the very active one who wants to eat and run to his play should be kept at the table for at least twenty or thirty minutes so that he will not be tempted to bolt his food.

The evening meal must be simple, since bedtime is not far away. A creamed vegetable soup with toast or crackers, a cooked vegetable and bacon on toast, a soft-cooked egg with a baked potato, milk toast, cereal and milk are examples of suitable hot dishes. There should be milk to drink, bread and butter with stewed fruit or a simple pudding for dessert.

As other foods are built into the diet around the quart of milk which forms its broad and sure foundation, the proportion of the total calories coming from the milk will naturally be less, but will never be an insignificant part of the whole. Good distribution of calories for children six to twelve years of age will usually have more than one-third and less than one-half of the calories contributed by milk.

Distribution of Calories for Well-Balanced Diets of Elementary School Children

Class of Food	Per Cent of Total Calories for Different Ages		
	6–7 Years	8–9 Years	10–12 Years
I. Food from cereal grains	25	24	22
II. Milk	45	40	34
III. Vegetables and fruit	14	15	17
IV. Butter	10	12	13
V. Sugar	3	4	6
VI. Eggs, cheese, meat, and other flesh foods	4	5	8

All of these will yield adequate diets provided the foods are selected with regard to good sources of iron and vitamin C.

High School Boys and Girls

By the time a boy or girl is twelve years old, the upper elementary or junior high school will usually have been reached, and the period of adolescence will have begun. In this period, lasting about ten years, there is a gradual transition from childhood to maturity. Growth, which has been proceeding with a weight increase averaging between 5 and 6 pounds a year is accelerated about the twelfth year in girls and the thirteenth in boys, as indicated by the following table:

RATE OF GROWTH FOR BOYS OF SCHOOL AGE

AGE—YEAR		6	7	8	9	10	11	12	13	14	15	16	17	18	19
Average Height (inches)	Short	43	45	47	49	51	53	54	56	58	60	62	64	65	65
	Medium	46	48	50	52	54	56	58	60	63	65	67	68	69	69
	Tall	49	51	53	55	57	59	61	64	67	70	72	72	73	73
Average Annual Gain in Weight (lbs.)	Short	3	4	5	5	5	4	8	9	11	14	13	7	3	
	Medium	4	5	6	6	6	7	9	11	15	11	8	4	3	
	Tall	5		7	7	7	8	12	16	11	9	7	3	4	

In most of the years between 6 and 17 the average growth in height of boys and girls is about 2 inches and in the years of greatest growth about 3 inches, though some boys grow 4 or 5 inches in the year of greatest growth. Just preceding the period of accelerated growth, the basal metabolism resembles that of the previous year or two, being relatively high for girls at the ages of 12 and 13, and for boys from 12 to 14; when puberty is established the metabolism falls rather sharply, as has already been shown in Chapter V.

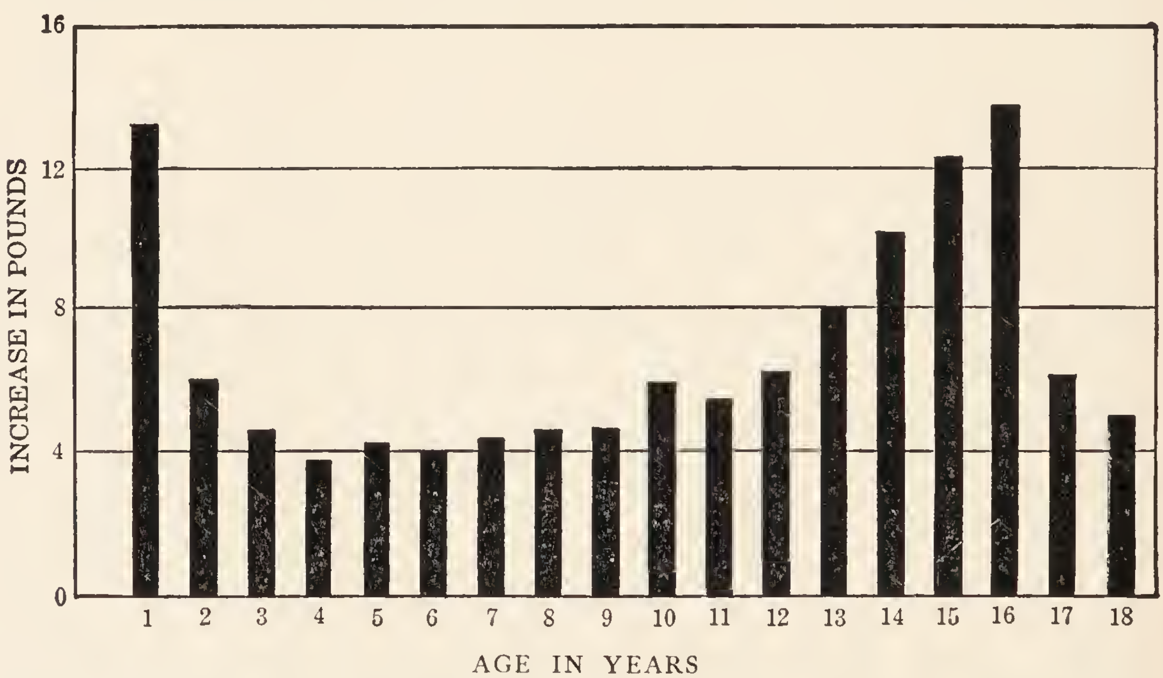

FIG. 85A.—Increase in Weight of Boys by Years from Birth to the Eighteenth Year.

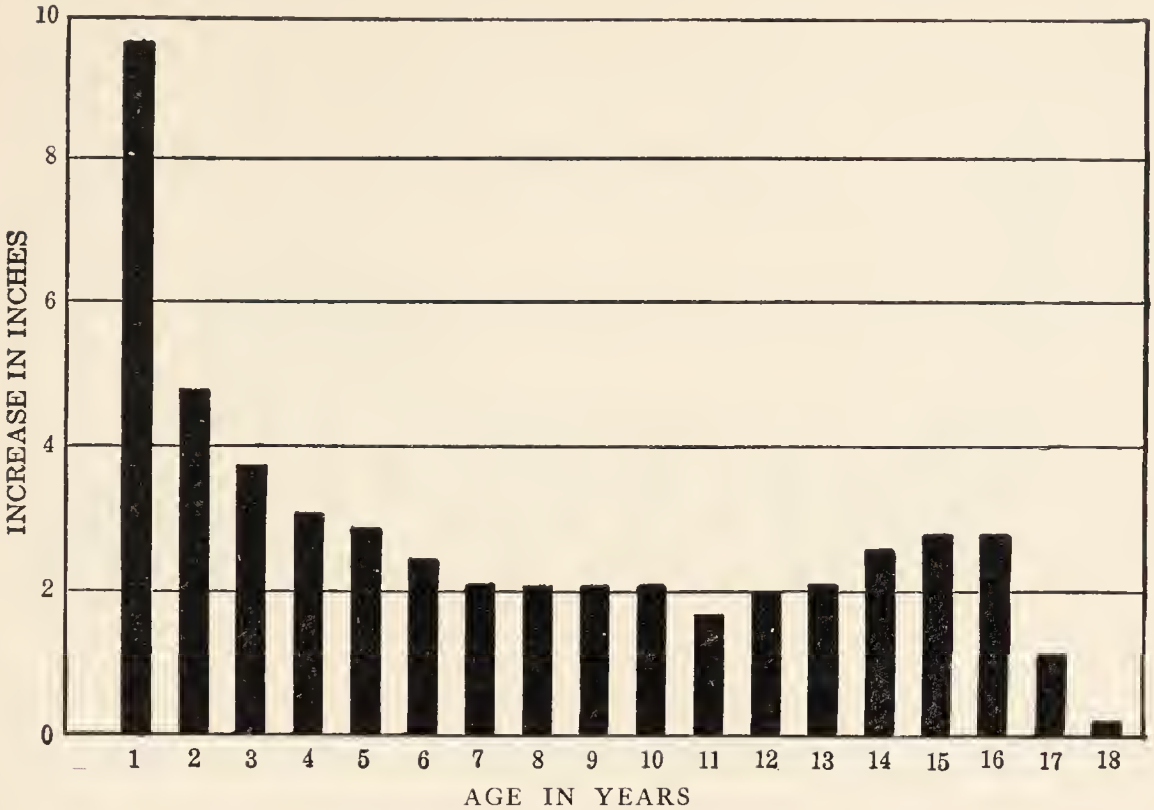

FIG. 85B.—Increase in Height of Boys from Birth to the Eighteenth Year.

For the whole period from 12 to 16 years in girls and 12 to 18 years in boys, the food requirements will be much higher than for adults of corresponding size, and emphasis must be put upon a diet which is capable of promoting the best possible growth. In nutritive quality it should be the equal of that for the younger children, and in quantity it will resemble the diets of toilers, such as farm laborers and stone workers.

In a study of the food consumption at St. Paul's

RATE OF GROWTH FOR GIRLS OF SCHOOL AGE

AGE-YEAR		6	7	8	9	10	11	12	13	14	15	16	17	18
Average Height (inches)	Short	43	45	47	49	50	52	54	57	59	60	61	61	61
	Medium	45	47	50	52	54	56	58	60	62	63	64	64	64
	Tall	47	50	53	55	57	59	62	64	66	66	67	67	67
Average Annual Gain in Weight (lbs.)	Short	4	4	4	5	6	6	10	13	10	7	2	1	
	Medium	5	5	6	7	8	10	13	10	6	4	3	1	
	Tall	6	8	8	9	11	13	9	8	4	4	1	1	

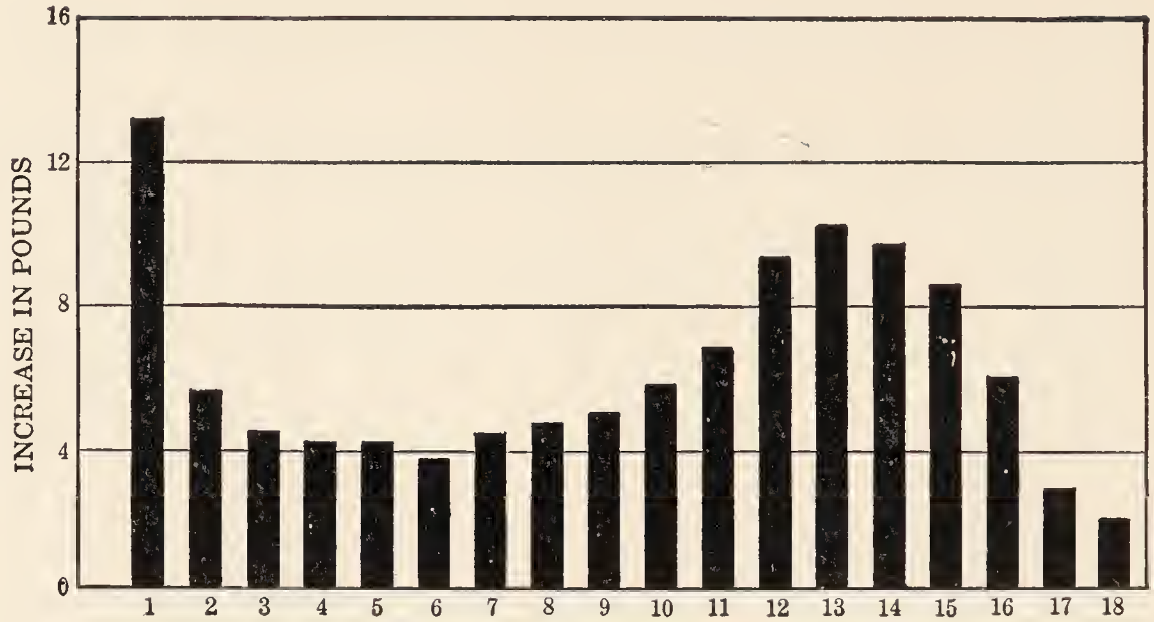

FIG. 86A.—Increase in Weight of Girls by Years from Birth to the Eighteenth Year.

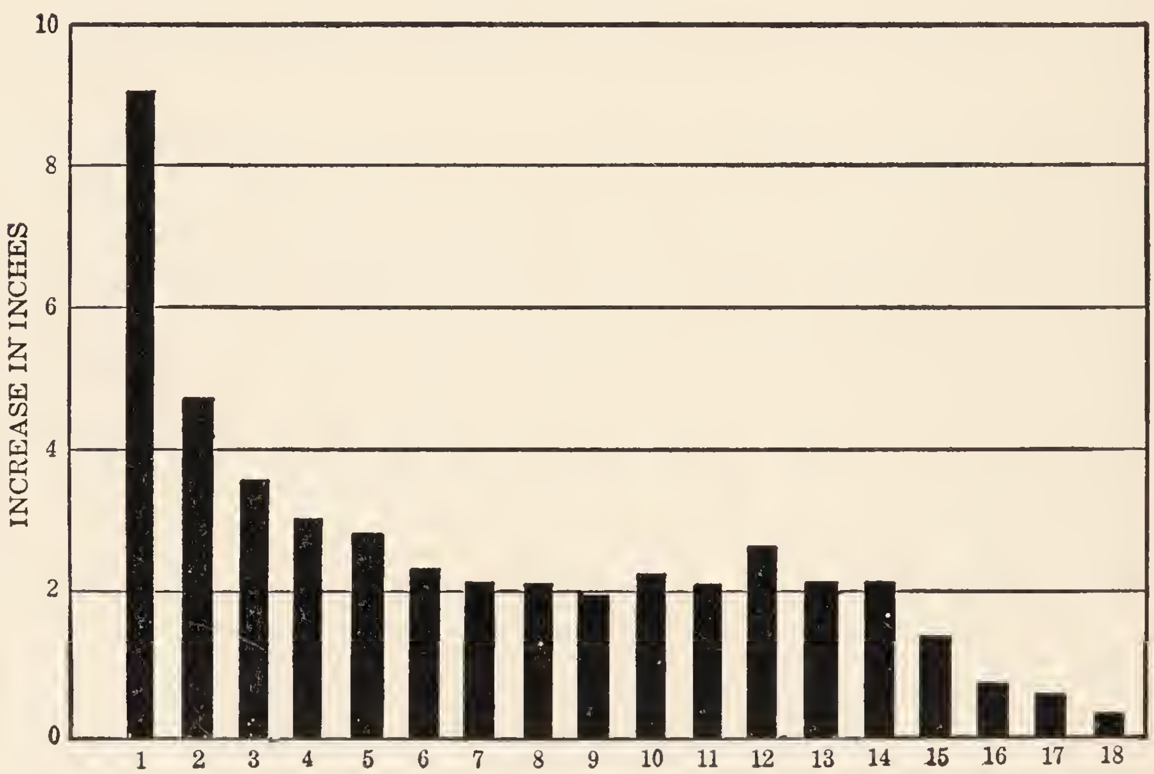

FIG. 86B.—Increase in Height of Girls from Birth to the Eighteenth Year.

School, Concord, New Hampshire, Dr. F. C. Gephart found that the boys between 13 and 15 years of age consumed over 100 calories per kilogram of body

weight, and those 16 and 17 years old about 82 calories per kilogram, making a total daily average of about 5,000 calories per boy per day for the whole school.[1] This study was a revelation of the food capacity of healthy adolescent boys leading an active life with much outdoor exercise. Their total fuel intake was about three times their basal metabolism.

How to Meet the High Food Needs of Boys and Girls

It is important that regularity of meals and the habit of eating plain wholesome food be maintained throughout the growing period. The one who faces a food requirement of from 1,000 to 1,500 calories per meal has occasion to give thought to the concentration of the diet, in order to insure a sufficiency without undue strain upon the digestive tract on the one hand or "meals at all hours." In *Seventeen*, Booth Tarkington has well depicted the tendency of the voracious age, in Jane, who is continually eating bread and apple sauce and brown sugar. That is not the best way, however, to meet the high food needs of adolescence. With care, the needed calories can be given for the most part in three regular meals, though opportunity to secure a little extra nourishment in the form of bread and butter, or crackers and milk, is often necessary.

A quart of milk a day should be allowed for each boy and girl, and if this is all taken as a beverage more may be used in cooking. The use of foods from

[1] Gephart, F. C. "Report of a Dietary Study of St. Paul's School, Concord, New Hampshire." *Boston Medical and Surgical Journal*, Vol. 176, page 17 (1917).

the cereal grains should be encouraged; various forms of bread are most useful, especially those of whole grains reinforced with nuts, dates, raisins, etc. Sweet dried fruits (dates, raisins, and figs) with their high fuel and ash values admirably supplement fresh fruits, and can be used in many ways. That an excellent luncheon can be prepared of figs, peanuts, and bread and butter has already been shown on page 355. Vegetables whose fuel value is low can be cooked with more butter or with white sauce, and salads can now have the cream or oil dressings which add so many calories in a small volume, provided they are not highly seasoned. Meat, while not a necessity, is an acceptable addition to the diet by reason of its appetizing properties and its power of giving the "staying" qualities which are such a desideratum at this age. It should be borne in mind that meat needs supplementing always by milk and vegetables, to give the calcium and vitamins which it lacks. It is interesting to see how meat, which lacks calcium and vitamins A and C, can be supplemented by milk and potato to make a well-balanced ration.

How Milk and Potato Supplement Meat

		Shares					Vitamins		
Food Material	Measure	Cal.	Pro.	Ca	P	Fe	A	B	C
Beef, med. fat	4 ounces	2.7	8.0	0.5	5.0	4.6	+	++	−
Milk	1 cup	1.7	3.2	12.9	5.2	1.2	+++	++	+?
Potato	2 medium	2.0	2.2	1.4	3.2	6.4	+	++	++
Total		6.4	13.4	14.8	13.4	12.2			

Other Considerations Influencing Choice of Food

The kinds of food habits which boys and girls form as they come to make their own choices are the food

habits they tend to carry over into adult life. A taste for plain, wholesome food, simply prepared, is a most valuable nutritional safeguard, and should be fostered in every possible way. If the appetite is not "up to" milk, vegetables, and fruits well cooked, and served accompanied by good bread and butter, something is wrong with the mode of life and the remedy is not highly seasoned food, such as "hot dogs," pickles, mince pie, or ice cream soda. Often what is most needed is more sleep, less excitement and fewer temptations to make eating "the great indoor sport."

Boys are more likely than girls to accept without protest a simple régime provided it really gives them a diet which appeases their chronic hunger. Quantity is the great consideration. Girls, whose urge to eat is not so compelling, pay more attention to the esthetic aspects of their diet. This is somewhat true even of girls leading active lives and taking their recreation in the form of outdoor sports. It will cost just as much to feed a girl as a boy although she eats a third less calories, because the calories she does eat must carry nearly as much building and regulatory material as his, and her normal food intake is less sustained by the demand of hunger and more through the appeal which the food makes to the eye. Many of the dietary problems presented by girls can be met ideally only as physical perfection can be made to seem worth working for. Not yet do women as a class take pride in physical fitness; on the contrary many, even to-day, take offense at any suggestion that they are perfectly well and begin to parade their disabilities. A girl must see advantages in health in order to be willing to strive

for it. Where thinness is admired she will work for thinness; where fatness is regarded as a mark of beauty, she will do her best to be fat. Her desire for beauty and praise far outruns her desire for food, and it will only be as higher ideals are developed that she will consciously endeavor to live hygienically. Her diet should be chosen with regard to its appearance and flavor, with emphasis upon growth-promoting factors. Fruit, eggs, milk, fresh vegetables, and nuts, along with a quart of milk a day, may well constitute a large part of the dietary at this time. Cakes, pies, fancy desserts, and candy cut down the proportion of ash and vitamins and are likely to disturb digestion. For the sake of good teeth and hair and a clear complexion they should be ruled out as far as possible. There is no better habit than that of persistently choosing simply-prepared foods of delicate flavor. Any tendency to highly flavored foods, whether sweets, pickles, pepper, catsup, or other so-called food adjuncts, every one should learn to curb in himself, not because of any immediate harm but because wise food habits acquired and maintained are the surest and easiest road to good nutrition so far as choice of food is a factor, while the habit of demanding highly seasoned food is bound to grow, and make the more wholesome plain foods distasteful.

The best regulator of appetite is plenty of fresh air and sunshine, with long hours of sleep at night. Regular meals should be insisted upon, even if little food be eaten, and if a girl is underweight, more rest should be taken to cut down energy expenditure and make it balance food intake.

Since adolescent boys have a greater need of fuel

foods than adolescent girls, the distribution of the typical food groups will vary with the total number of calories required. The following table suggests distributions suitable for different levels of energy intake for high school boys and girls:

Distribution of Calories for Adequate Diets of High School Boys and Girls

	Percentage of Total Calories Required per Day			
	Boys			Girls
Class of Food	5,000 Calories	4,000 Calories	3,000 Calories	2,300–2,800 Calories
I. Food from cereal grains (including bread)	27	26	22	18
II. Milk	15	18	24	25
III. Vegetables and fruits	18	18	18	20
IV. Fats	18	18	18	18
V. Sugars	10	10	10	10
VI. Eggs, cheese, meat, etc.	12	10	8	9

The test of any such plan is the nutritive value of a dietary based upon it. In the two which follow, one worked out in detail for a boy requiring 5,000 calories per day and the other for a girl requiring 2,500, we have evidence that there has been adequate provision of building materials as well as calories, and we have every reason to believe that the vitamin supply is ample. Nevertheless, during this period of rapid growth, the inclusion of a daily portion of cod-liver oil in the winter season may be regarded as an additional safeguard, not only because it furnishes vitamin D, but because it also adds to the reserves of vitamin A.

SELECTION OF FOOD MATERIALS FOR A BOY REQUIRING 5,000 CALORIES

Class of Food	Per Cent of Total Calories	Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Shares
I. Food from cereal grains (including bread)	27	13.5	White rolls	2 rolls	2.00
			Whole wheat bread	6 slices	3.00
			Crackers, graham	8 crackers	2.00
			Oatmeal	½ cup	3.00
			Flour, white	4/5 cup	3.50
II. Milk	15	7.5	Milk	38 ounces	7.50
III. Vegetables and fruits	18	9.0	Potatoes	3 medium	3.20
			Cabbage (shredded)	1 cup	0.30
			Peas	¾ cup	1.00
			Dates	8 dates	2.00
			Apples	2 medium	1.50
			Lettuce	¼ head	0.25
			String beans	2¼ cups	0.75
IV. Fats	18	9.0	Butter	5 tbsp.	5.00
			Bacon (raw)	1 ounce	2.00
			Drippings	2 tbsp.	2.00
V. Sugars	10	5.0	Sugar, granulated	6 tbsp.	3.00
			Molasses	1/5 cup	2.00
VI. Eggs, cheese, meat, etc.	12	6.0	Beef, medium fat	5 ounces	3.50
			Eggs	3 eggs	2.50

The food materials are chosen, first, with reference to the total calories, so that each group may be adequately represented; and second, within the groups, to make each group carry ash constituents and vitamins. Part of the cereal group is from foods in which the bran is retained; the fruit and vegetable group contains cabbage to be used raw as a rich source of vitamin C, and peas, lettuce and string beans, all rich in vitamin A; the fats include butter with its vitamin A; the sugars, molasses with a considerable amount of calcium and iron; and the meat group, eggs, rich in various kinds

of building material for the rapidly growing body, as well as vitamins A, B, and D.

A Day's Dietary for a Boy Requiring 5,000 Calories

Food Material	Shares Contributed to the Diet				
	Calories	Protein	Calcium	Phosphorus	Iron
White rolls	2.00	2.8	1.0	1.6	1.4
Whole wheat bread	3.00	4.7	2.6	4.8	3.9
Crackers, graham	2.00	2.8	1.8	3.8	3.8
Oatmeal	3.00	5.0	2.2	6.8	5.8
Flour, white	3.50	4.5	0.9	2.1	1.6
Milk	7.50	14.3	56.7	22.9	5.3
Potatoes	3.20	3.4	2.2	5.0	10.0
Cabbage	0.30	0.6	1.9	0.6	2.1
Peas	1.00	2.8	1.1	2.9	3.3
Dates	2.00	0.5	1.7	0.7	3.4
Apples	1.50	0.4	0.8	0.7	1.4
Lettuce	0.25	0.6	2.4	1.3	1.8
String beans	0.75	1.7	3.6	2.1	4.1
Butter	5.00	0.3	0.5	0.3	0.3
Bacon (raw)	2.00	1.4	0.1	1.0	1.0
Drippings	2.00	0.0	0.0	0.0	0.0
Sugar, granulated	3.00	0.0	0.0	0.0	0.0
Molasses	2.00	0.7	6.4	0.7	10.2
Beef, medium fat	3.50	10.2	0.7	6.8	5.9
Eggs	2.50	9.1	4.9	6.9	10.3
Total	50.00	65.8	91.5	71.0	75.6
Standard	50.00	50.0	50.0	50.0	50.0

A simple, wholesome menu, showing how these foods may be distributed among three meals, is shown below:

MENU

Breakfast	Luncheon	Dinner
Dates	Hash (meat and potato)	Meat with gravy
Oatmeal	Peas	Potatoes
Milk	Cabbage (slaw)	String beans
Toast	Whole wheat bread and butter	Lettuce
Bacon	Gingerbread	Rolls and butter
Eggs	Milk to drink	Apple Betty with milk and sugar
Milk to drink		Graham crackers
		Milk to drink

Significant Sources of Vitamins

	Vitamin A	Vitamin B	Vitamin C
Milk	+++	++	+?
Potatoes	+	++	++ (cooked 15 minutes)
Cabbage	+	++	+++ (raw)
Peas	++	++	++ (canned)
Lettuce	+	++	+++
String beans	++	++	++
Butter	+++	–	–
Eggs	+++	+	–

Selection of Food Materials for a Girl Requiring 2,500 Calories

Class of Food	Per Cent of Total Calories	Shares Required	Foods to Yield Shares Required	Measure of Food	Number of Shares
I. Food from cereal grains (including) bread)	17	4.25	Bread, white	2 rolls	1.00
			Bread, rye	2 slices	1.00
			Shredded wheat	1 biscuit	1.00
			Flour, white	5 tbsp.	1.25
II. Milk	25	6.25	Milk	32 ounces	6.25
III. Vegetables and fruit	20	5.00	Orange	1 medium	0.80
			Apple	1 medium	0.80
			Banana	1 medium	1.00
			Potato	1 large	1.50
			Lettuce	$^{2}/_{5}$ head	0.20
			Celery	$3^{1}/_{2}$ ounces	0.20
			String beans	$^{3}/_{4}$ cup	0.30
			Raisins	5 raisins	0.20
IV. Fats	18	4.50	Butter	3 tbsp.	3.00
			Other fat	$1^{1}/_{2}$ tbsp.	1.50
V. Sugars	10	2.50	Sugar, granulated	3 tbsp.	1.50
			Molasses	1 tbsp.	1.00
VI. Eggs, cheese, meat, etc.	10	2.50	Beef, lean	4 ounces	1.75
			Egg	one	0.75

In this dietary, as in the preceding one, the apportionment of a liberal percentage of the total calories to the vegetable-fruit group, along with a quart of milk and an egg, practically assures the adequacy of the

diet, but for conclusive evidence, the details are given in the following pages.

A Day's Dietary for a Girl Requiring 2,500 Calories

Foor Meterial	Shares Contributed to the Diet				
	Calories	Protein	Calcium	Phosphorus	Iron
Bread, white	1.00	1.4	0.5	0.8	0.7
Bread, rye	1.00	1.4	0.4	1.3	0.8
Shredded wheat	1.00	1.4	0.5	2.0	2.5
Flour, white	1.25	1.6	0.3	0.7	0.6
Milk	6.25	11.9	47.3	19.1	4.4
Orange	0.80	0.5	3.0	0.7	0.6
Apple	0.80	0.2	0.4	0.4	0.8
Banana	1.00	0.5	0.4	0.7	1.2
Potato	1.50	1.6	1.0	2.3	4.7
Lettuce	0.20	0.5	1.9	1.0	1.5
Celery	0.20	0.1	3.7	1.0	1.1
String beans	0.30	0.7	1.4	0.9	1.6
Raisins	0.20	0.0	0.2	0.2	0.6
Butter	3.00	0.2	0.3	0.2	0.2
Other fat	1.50	0.0	0.0	0.0	0.0
Sugar, granulated	1.50	0.0	0.0	0.0	0.0
Molasses	1.00	0.3	3.2	0.3	5.1
Beef, lean	1.75	9.5	0.6	5.8	7.1
Egg	0.75	2.7	1.5	2.1	3.0
Total	25.00	34.5	66.6	39.2	36.3
Standard	25.00	25.0	43.0	23.0	25.0

Note that the milk alone supplies more than the standard allowance for calcium, while all the vegetables and fruits together furnish only one-fourth as much as the milk; and also that they supplement the milk as to iron, yielding fully one-third of the total iron in the diet.

MENU

Breakfast	Luncheon	Dinner
Orange	Apple and celery salad	Meat
Shredded wheat	Rye bread and butter	Potato
Milk to drink	Molasses and raisin drop cake	String beans
Toasted roll and butter	Cocoa	Banana salad
		Roll and butter
		Baked custard

Significant Sources of Vitamins

	Vitamin A	Vitamin B	Vitamin c
Milk	+++	++	+?
Orange	+	++	+++
Apple	+	+	++
Banana	+	+	++
Potatoes	+	++	++ (cooked 15 minutes)
Lettuce	+	++	+++
Celery	–	++	?
String Beans	++	++	++
Butter	+++	–	–
Egg	+++	+	–

Section 3

WELL-BALANCED DIETS FOR FAMILY GROUPS

In a single family we expect to find differences of age—infants, children and adults; differences of activity—the liveliest of children and the most sedate of parents; differences of taste—the boy whose sole criterion of a good meal is "enough" and the delicate damsel who cannot even peck at a meal unless the whole setting of the table appeals to her soul. Each member of the family group has his own particular food requirements which are matters of fact not fancy, and yet each claims a seat at the family table; for this is not merely the place where sustenance is furnished for the body; it is also a center of the social life of the group, offering important training in the graces of human intercourse, and in the development of those esthetic standards of choice, preparation, and service of food which are an expression of the culture and refinement of the household.

In the majority of homes, the cost of food is a mat-

ter which requires much attention, but spending or saving must be done without impairing the nutritive value of the diet. A distinction must be made between food expenditures for nutriment and those for social purposes. Plain bread and milk makes a most nutritious meal at a very low cost, but it is considered too simple and unpretentious to be served at a banquet; it would seem as incongruous as going in a gingham dress or overalls. Each family must determine for itself the relationship between the expenditure for actual nourishment and the additional sum to be allowed for enjoyment and entertainment and maintenance of social prestige.

As it is outside the scope of this book to consider in detail the social aspects of the food problem, this discussion will be confined to the food requirements of a representative family group, and a plan for meeting them successfully so far as nutrition is concerned.

While the requirements of the individual members may seem to differ considerably, the divergences are more in quantity and mode of service than in kind of food. With minor adjustments, it is possible to keep Six, Sixteen, Thirty-six, and Forty-six well and happy on meals composed of practically the same ingredients, if suitably cooked and apportioned with discretion. Infants and children young enough to require specially prepared food are best cared for by themselves. They are not only likely to have a more carefully selected diet, but the children can also be more comfortably trained in good eating habits.

The energy requirements of the family group will be the sum of those of the individuals composing it.

In a family consisting of a father and mother and three young children they might be as follows:

ENERGY REQUIREMENTS OF A FAMILY WITH THREE CHILDREN UNDER 12 YEARS OF AGE

	Weight, kg.	Calories per kg.	Calories per Day
Father	70	42	2,940
Mother	56	40	2,240
Boy (10 yrs.)	30	75	2,250
Girl (8 yrs.)	25	70	1,750
Boy (6 yrs.)	18	80	1,440
Total			10,620

A household with older children and parents engaged in heavier manual labor would have higher requirements.

ENERGY REQUIREMENTS OF A FAMILY WITH THREE CHILDREN OVER 12 YEARS OF AGE

	Weight, kg.	Calories per kg.	Calories per day
Father	70	50	3,500
Mother	56	45	2,520
Boy (17 yrs.)	54	65	3,510
Girl (15 yrs.)	50	47	2,350
Boy (13 yrs.)	40	75	3,000
Total			14,880

Here seven years of growth on the part of the children have raised their calorie aggregate from 5,440 to 8,860 or 60 per cent, hence with no change in the activity of the adults the requirements at this later time would be increased by an amount equal to adding to the group one hard-working adult man (3,420 calories).

Taking our first estimate for the family with younger children, we may now state the various food requirements for a balanced diet in terms of shares.

Food Requirements of a Family of Five Expressed in Shares

	Calories	Protein	Calcium	Phosphorus	Iron
Father	29.4	29.4	29.4	29.4	29.4
Mother	22.4	22.4	22.4	22.4	22.4
Boy (10 yrs.)	22.5	22.5	43.0	23.0	22.5
Girl (8 yrs.)	17.5	17.5	43.0	23.0	17.5
Boy (6 yrs.)	14.4	14.4	43.0	23.0	14.4
Total	106.2	106.2	180.8	120.8	106.2

Moderately-Priced Family Dietaries

What selection of food is now going to insure a well-balanced diet? The calories cannot be apportioned to our common food groups in the same fashion as for an adult man, nor an adult woman, nor any one of the children. We must have a standard representative of the needs of the group as a whole.

To follow the rule of a quart of milk for each child and a pint for each adult will mean that about one-fourth of the total calories will come from this one item. In a moderately priced dietary another fourth, at least, should come from the cereal grains and among foods of this class selection should be made in such a way that at least one-half of the calories carry iron. The chief limitation upon fruits and vegetables will be cost. With care in selection, it is usually possible to secure from one-sixth to one-fifth of the total calories from this group without making the cost excessive. Dried fruits and vegetables always give a high nutritive return on the money invested, and at certain seasons canned ones

are also less expensive than many fresh ones. Fresh fruits and vegetables should never be excluded entirely, but it is well to remember that canned tomatoes, fresh raw cabbage, and potatoes will go far toward supplying vitamin C which is the dietary essential not supplied by ordinary dried fruits and vegetables. If to these are added spinach, string beans or green peas fresh or canned, carrots and oranges, using potatoes and two of these other vegetables daily, one may rest assured that one-sixth of the calories in the form of fruits and vegetables will afford adequate protection, assuming the milk and cereal foods to be chosen as already suggested.

As to fats there is a wide range, but the quantity must not be too large or the diet will be difficult to digest; not too small or some one may fail to get enough calories. In a children's institution it was found that the diet was excellent in almost every other respect, but had a low proportion of fat. Most of the girls grew very well on the diet, but the boys, especially the larger ones, did not, because they did not get sufficiently large servings of the other foods to make up for the lack of fat. Increasing this raised the fuel value without any visible change in the character of the meals, but much to the advantage of the children.

With one-fourth of the total calories coming from milk and one-sixth from a good assortment of fruits and vegetables, the kind of fat is not as important as where less milk is used, for each quart of milk will yield over an ounce and a half of butter. As butter fat is an important source of vitamin A, it should not be excluded from any diet, but when taken in milk,

there is less need of an additional supply of vitamin A and other fats may be safely used, especially if the vegetables are chosen with regard to vitamin A. Fresh spinach, for instance, weight for weight, has as much vitamin A as good butter.

Sugar and syrups, because of their attractive flavor and cheapness, tend to be used too freely in economical diets, displacing foods which are more important. Pure cane molasses is significant for calcium and iron, and in a family where there are growing children, may well be used to replace some cane sugar. But sweet foods are likely to overstimulate love of flavor and cut down the appetite for mildly flavored foods. The total amount of sweets should always be moderate, and from 10 to 12 per cent of the total calories seems to be a very good rule.

Meat is almost invariably one of the most expensive items and since its cost is out of proportion to its nutritive value, it should be used chiefly to give zest to a meal. One-half an ounce of meat for a child 8 to 10 years old, one ounce for a child 11 to 14, and two ounces for an older child or grown-up, is a very suitable amount for a meal. Liver, which is much richer in iron and vitamins A and B and usually relatively cheap, may well be used part of the time instead of muscle tissue.

Eggs, although expensive, are especially significant in the diet of young children and should be furnished at least three or four times a week for them even if not provided freely for the adults. When the other food groups have been provided for properly, the proportion of the total calories to be allotted to the meat and egg group will be small.

Cheese may be regarded as a substitute for meat, and is therefore included in this group. But it may also be regarded as a partial substitute for milk, and a part of the calories assigned to milk might be taken as cheese.

DISTRIBUTION OF CALORIES IN A MODERATELY-PRICED DIETARY

CLASS OF FOOD	PER CENT OF TOTAL CALORIES
I. Foods from cereal grains (including bread)	25–30
II. Milk	25
III. Vegetables and fruits	15–20
IV. Fats and oils	10–20
V. Sugars	10–12
VI. Meat, eggs, etc.	8–15

The construction of a dietary from such a plan for the distribution of calories is not difficult, as the table below will show:

SELECTION OF FOOD FOR A MODERATELY-PRICED FAMILY DIETARY

CLASS OF FOOD	PER CENT OF TOTAL CALORIES	SHARES REQUIRED	FOOD TO YIELD SHARES REQUIRED	AMOUNT OF FOOD	NUMBER OF SHARES
I. Foods from cereal grains (including bread)	25	26	Bread, white	8 1/4 ounces	6
			Bread, graham	9 1/2 ounces	7
			Rolled oats	1 cup	6
			Flour, white	3/4 cup	3
			Rice	1/2 cup	4
II. Milk	25	27	Milk	4 quarts	27
III. Vegetables and fruits	17	18	Prunes	12 medium	3
			Oranges	5 small	3
			Potatoes	6 medium	6
			Lettuce	2 heads	1
			Cabbage	5 cups, shredded	1
				3 cups, cubes	4
IV. Fats	15	16	Butter	5 1/2 ounces	11
			Bacon	2 1/2 ounces	4
V. Sugar	10	11	Sugar—granulated	1 1/3 cups	11
VI. Eggs, cheese, meat, etc.	8	8	Eggs	5 eggs	4
			Beef, lean	9 ounces	4

The graham bread and oatmeal are chosen as the iron-bearing half of the calories from cereal foods, the fruits and vegetables are, with the exception of prunes, sources of vitamin C; oranges, lettuce, cabbage, and carrots are good sources of vitamin A. Bacon has been included with the idea that the bacon fat will be used in cooking. Ten per cent of the total calories means ten ounces of sugar, which is certainly not restrictive to the point of hardship. One egg has been furnished for each person. That the dietary will meet the estimated requirements of the family is demonstrated by the table following:

A Moderately-Priced Family Dietary

Food	Shares Contributed to the Diet				
	Calories	Protein	Calcium	Phosphorus	Iron
Bread, white	6	9.4	1.3	3.2	3.1
Bread, graham	7	9.6	6.1	13.4	13.4
Rolled oats	6	10.1	4.4	13.5	11.5
Rice	4	3.6	0.2	2.4	2.0
Flour, white	3	3.8	0.8	1.8	1.4
Milk	27	51.3	204.1	82.4	18.9
Prunes	3	0.8	2.3	2.4	6.0
Oranges	3	1.9	11.5	2.7	2.3
Potatoes	6	6.4	4.1	9.4	18.7
Lettuce	1	2.5	9.7	5.1	7.3
Cabbage	1	2.0	6.2	2.1	7.0
Carrots	4	3.9	21.6	9.2	10.6
Butter	11	0.6	1.0	0.6	0.7
Bacon	4	2.7	0.2	1.6	1.7
Sugar	11	0.0	0.0	0.0	0.0
Eggs	4	14.5	7.8	11.1	16.4
Beef, lean	4	21.8	1.5	13.3	16.4
Totals	105	144.9	282.8	174.2	137.4
Standard	106	106.0	180.0	120.0	106.0

MENU

Breakfast	Luncheon	Dinner
Oranges	Omelet with bacon	Beef stew with dumplings
Oatmeal	Creamed carrots	Potatoes
Toast and butter	Bread and butter	Bread and butter
Milk to drink	Cabbage salad	Lettuce salad
	Prune pudding	Rice pudding with milk
	Milk to drink	

This dietary is not only adequate but also suitable for the children with a little rearrangement of the menu. The 6- and 8-year-olds would have orange juice for breakfast, stewed cabbage instead of the raw salad for luncheon, perhaps the following for supper:

Cream of carrot soup
Toast with a little broth from the stew
Baked potato
Rice pudding
Milk to drink

Family Dietaries with Little Limitation of Cost

As necessity for economy decreases, less cereal food is likely to be used, since this is the least attractively flavored of all types of food in the diet. If the cereals are partly replaced by fruits and vegetables, less attention will have to be devoted to the kind of cereal food used, as the fruits and vegetables will quite regularly increase the mineral and vitamin content of the ration. There may be a tendency to use less milk because of its mild flavor, when many foods of more pronounced flavor can be bought, but even if the fats used are chiefly butter and cream, milk is still needed, since in no other way can liberal calcium be guaranteed. A well-to-do family will find that the following distribution of calories will serve as a guide to a properly assorted diet:

Distribution of Calories in a Dietary without Cost Restrictions

Class of Food	Per Cent of Total Calories
I. Foods from cereal grains (including bread)	20
II. Milk	20–25
III. Vegetables and fruits	18–24
IV. Fats and oils	15–20
V. Sugars	10–12
VI. Meats, eggs, cheese, etc.	10–15

Selection of food for the family on this basis might be made as follows:

Selection of Food for a Family Dietary without Cost Restrictions

Class of Food	Per Cent of Total Calories	Shares Required	Food to Yield Shares Required	Amount of Food	Number of Shares
I. Food from cereal grains (including bread)	20	21	Farina, dark	5/6 cup	5
			Bread, whole wheat	5 3/4 ozs.	4
			Rolls, white	6 rolls	6
			Cookies, plain	10 small	4
			Flour	2 tbsp.	2
II. Milk	25	27	Milk	4 quarts	27
III. Vegetables and fruit	20	21	Grapefruit	2 large	3
			Potatoes	5 med.	5
			Celery	2 cups	½
			Lettuce	1 head	½
			Cauliflower	1 head	2
			Bananas	5 med.	5
			Apple	1 large	1
			Tomatoes	3 1/2 cups	2
			Pineapple, can'd	1/2 cup	2
IV. Fats and oils	15	16	Butter	1/2 cup	8
			Cream	1 cup	8
V. Sugars	10	11	Sugar	1 1/3 cups	11
VI. Meats, eggs, cheese, etc.	10	10	Eggs	4 eggs	3
			Beef, lean	11 oz.	5
			Cheese	1 2/3 oz.	2

MENU

Breakfast	Luncheon	Dinner
Grapefruit	Bouillon	Roast beef
Farina, milk and sugar	Cheese fondue	Mashed potatoes
Toast and butter	Stewed tomatoes	Cauliflower
Coffee with cream for adults	Rolls and butter	Bread and butter
Milk for children	Baked bananas	Lettuce, apple, and celery salad
	Cookies	Junket with pineapple and whipped cream
	Milk to drink	Milk to drink

In this dietary there will be more need for adjustment to the young children than in the preceding one. Orange juice is preferable for their breakfast on account of its lower acidity. A cream tomato soup with toast squares might form the foundation of the luncheon for the 6- and 8-year olds, with a vegetable saved for the purpose from the previous dinner and plain boiled potatoes. Whole wheat bread should be substituted for the rolls, but the baked bananas and plain cookies would be suitable for dessert.

The younger children's evening meal would probably come before the family dinner. It should also be very simple, consisting perhaps of a creamy egg on toast, whole wheat bread and butter, stewed prunes, and milk to drink.

Very Economical Family Dietaries

Among people of very limited means the largest item in the budget is food, and there must be careful planning to have anything left for other necessities. Food economies can be effected in a variety of ways without sacrifice of nutritive value. The first move should generally be to increase the consumption of the

foods from cereal grains, and to see that these are made the carriers of mineral constituents and vitamins so far as they are capable of yielding them. The use of the whole grain instead of the refined product is far more important here than in a diet where cereals constitute one-quarter or less of the total calories. The striking lesson that a diet of whole wheat and whole milk with a little added salt, is capable of sustaining rats through 21 generations should be taken to heart. By skillful cookery it is possible to vary a diet in which cereals figure largely. Mrs. Ewing, pioneer teacher of home economics and a famous maker of bread, used to say that she could keep any family contented with its meals if she could only make its bread.

Among vegetables and fruits economies must be sought in use of foods at the height of their season and not when out of season and therefore expensive. Purchasing should be done with regard to nutritive value rather than size or color, but every effort should be made in buying fresh vegetables to have them as fresh as possible, since the flavor depends so much upon this. All the vegetables should be cooked with regard to conserving ash constituents and vitamins, when the quantity is limited. Steaming is often the best method, but the water in which vegetables are cooked can be saved for soups or sauces.

Milk is always one of the best food investments that it is possible to make. Where fresh milk of good quality is not to be had at a fair price in comparison with other foods, it is now possible to get dried whole milk which has lost nothing but water in the drying process and can readily be reconstituted by adding a suitable

amount of water. The dried milk is also very useful when ice is not available.

With liberal allowances of milk, butter is not a necessity and fat from meat, vegetable oils, and hardened vegetable fats of various kinds must largely take its place. There are butter substitutes which are just as wholesome as butter and carry as many calories, though they are not full butter equivalents when they carry as little vitamin A as most of them do.

Cream is always more expensive than milk, and in an economical diet should not be bought as such, but be taken from the milk purchased. The habit of using milk instead of cream on cereals, puddings, etc., is a desirable one to cultivate.

Meat cannot figure prominently in an economical diet since it is usually the most expensive food. Even cheap cuts are not so very cheap, or else they consist largely of waste. Meat is appetizing and therefore a certain amount, especially for adults, is desirable. But the quantity consumed at a meal need not be large, and should be used in such a way as to extend its flavor over as much bread and other bland food as possible, for thus it does its best service. What has been said about eggs and cheese in discussing moderately priced diets also applies here.

Distribution of Calories for a Very Economical Dietary

Class of Food	Per Cent of Total Calories
I. Food from cereal grains (including bread)	30–40
II. Milk	20–25
III. Vegetables and fruits	12–15
IV. Fats and oils	10–12
V. Sugars	10–12
VI. Meats, eggs, cheese, etc.	5–10

Selection of Food for a Very Economical Dietary

Class of Food	Per Cent of Total Calories	Shares Required	Food to Yield Shares Required	Amount of Food	Number of Shares
I. Food from cereal grains (including bread)	35	37	Flour, white	6 tbsp	2
			Cornmeal	6 tbsp.	2
			Rolled oats	$2^5/_8$ cups	8
			Bread, whole wheat	$14\frac{1}{4}$ oz.	10
			Bread, white	$5^1/_2$ oz.	4
			Bread, rye	$15^1/_4$ oz.	11
II. Milk	25	27	Milk	4 quarts	27
III. Vegetables and fruit	12	13	Potatoes	5 med.	5
			Tomatoes	3 med.	1
			Onions	12 med.	3
			Cabbage	11 ozs.	1
			Beans, dried Lima	$^3/_8$ cup	3
IV. Fats and oils	12	13	Butter substitute	$3^1/_4$ ozs.	7
			Vegetable or meat fat	$2^3/_4$ ozs.	6
V. Sugars	10	11	Molasses	$^1/_2$ cup	5
			Sugar, granulated	$^3/_4$ cup	6
VI. Meat, eggs, cheese, etc.	6	6	Eggs	3 eggs	2
			Beef, lean round	9 ozs.	4

MENU

Breakfast	Luncheon	Dinner
Oatmeal, milk and sugar	Stewed Lima beans	Meat loaf
Toast	Creamed onions	Potatoes
Milk to drink	Rye bread and butter substitute	Scalloped tomatoes
	Indian meal pudding	Cabbage (slaw)
	Milk to drink	Whole wheat bread and butter substitute
		Bread pudding
		Milk to drink

To put such programs into effect means considerable modification of most people's way of thinking about food and of planning meals. Milk has been regarded by too many as food only for babies; one mother expressed a

not uncommon idea when she said, "My boy is fourteen years old and I am surprised to find that he can still digest milk!" But the science of nutrition has taught us that no better foundation for the diet can be found either for children or adults than a liberal amount of milk. Dietaries such as have been outlined in this chapter give little opportunity for fancy cooking. If the suggestions in this book are followed, milk soups, milk puddings, and many other milk dishes will become a prominent part of the régime unless the simpler method of drinking most of the milk is followed by all of the family. Knowledge of how to have a simple diet which is nutritionally the best should help busy housewives to lighten their labors in the kitchen and find time for other interests, such as a larger share in the education of their children. It ought to be a great comfort to a mother to know that she is doing her children a real kindness when she gives them a supper of plain bread and milk or cereal and milk. Scientific knowledge makes possible simplification of the menu without risk of an inadequate diet.

The situation is similar with regard to economy in food. To choose what will fit a slim purse regardless of nutritive value is likely to bring underfeeding on some count or other, perhaps on several counts at once. A common tendency when money is scarce is to secure calories largely from breadstuffs, sugars and syrups, plus muscle meat, with the result that the dietary is low in mineral constituents and vitamins and not sufficiently laxative. What can be accomplished with regard to ash constituents when foods are chosen to meet recognized needs is exemplified in the Very Economical Dietary described above. A

comparison of the protein, calcium, phosphorus and iron in this and the two more expensive dietaries shows that the cheapest one is in no respect inferior, as to quantity, and there is every reason to believe that there is no essential difference in usefulness to the body.

A COMPARISON OF THE NUTRITIVE VALUE OF THREE FAMILY DIETARIES OF DIFFERING COST

Cost Level	Shares Contributed				
	Calories	Protein	Calcium	Phosphorus	Iron
High-Priced (page 437)	106	144	313	179	125
Moderately-Priced (page 435)	105	145	283	174	137
Low-Priced (page 441)	107	157	267	180	149
Standard	106	106	180	120	106

Any low-priced dietary needs to be specially guarded as to vitamins A and C. True safety lies only in selection of foods specially rich in these important factors. The higher-priced dietaries have the advantage of a greater variety of vitamin-bearing foods, and if a liberal percentage of the total calories is derived from an assortment of fruits and vegetables, vitamin C is not likely to be inadequate. The low-priced dietary, however, can be protected only by conscious effort to use freely a limited number of cheaper foods which are unquestionably of high vitamin C content, such as tomatoes, raw cabbage, raw onions, raw carrots or other fresh vegetables and fresh fruits when they can be purchased to advantage. The higher-priced dietary is also more easily safeguarded with regard to vitamin A, because of the predilection of people generally for butter, eggs and cream. In the economical dietary, the liberal use of milk is the best guarantee of a safe

amount of vitamin A as well as the best all-round food investment.

Chief Sources of Vitamins in Three Family Dietaries of Differing Cost

Cost Level	Vitamins		
	A	B	C
High-Priced (page 437)	Milk Butter Cream Eggs Cheese Lettuce Tomatoes	Milk Whole wheat bread Dark farina Potatoes Celery Cauliflower Bananas Apple Tomatoes Pineapple Eggs	Grapefruit Potatoes Lettuce Bananas Tomatoes

Cost Level	Vitamins		
	A	B	C
Moderately-Priced (page 435)	Milk Butter Eggs Cabbage (if green) Lettuce	Milk Graham bread Rolled oats Prunes Oranges Potatoes Lettuce Cabbage	Oranges Potatoes Lettuce Cabbage (raw)

Cost Level	Vitamins		
	A	B	C
Low-Priced (page 441)	Milk Tomatoes Cabbage (if green)	Milk Whole wheat bread Rye bread Potatoes Tomatoes Onions Cabbage Lima beans (dried)	Tomatoes Potatoes Cabbage (raw)

That it will pay to master the art of selecting an adequate diet at any cost level has been the lesson taught by the most careful investigations in the field of nutrition. "With heredity and all the conditions of environment except food, the same, those enjoying the better balanced diet are bound to inherit the earth." *Sherman.*

Section 4

SPECIAL FOOD NEEDS OF MOTHERS AND BABIES

"The baby owes nothing at all to his parents. He has no responsibilities, no duties. The parents owe everything to the baby. Their responsibility to him is complete. Their duties are endless. They are most solemnly bound to use every effort to keep him in good health and happy, to build up his constitution to fit him for the world, and to launch him upon the world. In time their responsibility lessens but it never disappears; whatever happens, it cannot end. In other words, we are bound to see that children are given the best opportunity to develop to the limit of their growth capacity." If we accept this statement by Arnold Bennett as the modern baby's bill of rights, we are solemnly bound to apply all the accumulated knowledge in regard to the nutrition of the growing organism to the problem of feeding the baby.

Good nutrition for the baby begins with the mother. During prenatal life growth goes on at a rate never equaled after birth. The profound effect of diet upon the well-being of the fetus has been repeatedly demonstrated in the case of laboratory animals. Vitamins A,

B, and E have each been found to influence gestation in its own specific way. Observations on human life reveal similar effects. Among women in the Philippines found to be suffering from beriberi (due to lack of vitamin B) it is reported that 80 per cent of the pregnancies result in abortion or in death of the child during the first year of life. Reynolds and Macomber have reported cases of women in whom sterility was apparently cured by a change from a diet habitually low in vitamin A to one rich in it. The Wisconsin experiment with cattle showed the disastrous result of several dietary deficiencies in the same ration (for instance of vitamin A, calcium and sodium chloride in wheat). The influence of a shortage of iodine upon the development of the embryo has been demonstrated not only for various farm animals, but also for the human species. Protracted undernutrition of mothers in Central Europe as a result of the World War resulted in a decrease in the weight of the newborn, in a lowering of the capacity for milk production, and in the appearance of rickets in the offspring. If a child is to be well-born, the mother's diet throughout pregnancy is a matter of grave importance. Yet a publication of the Children's Bureau calls the nine months before a baby is born "the most neglected period of his existence," [1] This is really an indictment of the poor quality of many adult diets, since it is based on the premise that "few mothers get enough of the vitamin and mineral foods needed for health, growth, and the normal regulation of body processes." The proper

[1] *What Builds Babies?* Folder No. 4, Children's Bureau. United States Department of Labor, 1925.

time to begin to improve the diet of the mother is in her own childhood so that she may come to womanhood with her body well developed and at all times in an optimal state of nutrition. Then the diet of pregnancy need differ only in certain minor details from that to which she has been accustomed.

Nutrition Before Birth

Pregnancy is a period of growth and the diet must be relatively rich in all growth-promoting substances. There need be, however, no marked increase in the total energy value of the diet. The gain in weight of the fetus is at first scarcely more than one gram per day. By the sixth month it is about 10 grams per day, but about one-half of the weight of the newborn is acquired during the last 8 weeks before birth.

Studies of the basal metabolism throughout the gestation period show that it is only in the last three months that the metabolism of the fetus and the increased weight of the mother (amounting to about 20 pounds) have any noteworthy effect upon the total energy requirement of the mother, and then the increase will be almost directly proportional to the increase in body weight. A woman of sedentary habits will require from 2,400 to 2,800 calories per day, while a fairly active one is not likely to need over 2,800 to 3,000.

For the construction of new body tissue there must be available all essential amino acids, hence the quality of the protein of the diet is important. The storage of mineral elements increases as the fetus develops as the following table shows:

Changes in Calcium, Phosphorus and Iron with the Growth of the Fetus[1]

Age of Fetus Months	Weight of Fetus Kilograms	Calcium Grams	Phosphorus Grams	Iron Grams
4.0	0.522	3.3	2.3	0.042
5.0	0.570	4.0	2.1	0.034
5.5	0.800	4.2	2.8	0.052
6.0	1.165	7.6	4.7	0.084
6.5	1.285	8.0	5.1	0.086
9.0	2.720	28.0	15.0	0.264

[1] Compiled from data cited by Feldman, W. M. *Principles of Ante-natal and Post-natal Child Physiology*. Longmans, Green & Co., page 130, 1920.

The teeth are all under construction before birth. They begin to form by the third month and at birth all the 20 teeth of the first set are inside the jaw and their crowns almost completely calcified. Their normal development depends not only upon mineral elements (especially calcium and phosphorus), but also upon conditions favorable to the utilization of these elements which are insured by liberal amounts of vitamins C and D or the equivalent of D in sunlight or ultra-violet light. The demands for vitamin A are higher in pregnancy than in growth, for it has been shown by Sherman and MacLeod that "a proportion of vitamin A in the food sufficient to support normal growth and maintain every appearance of good health, for a long time at least, may still be insufficient to meet the added nutritive demands of successful reproduction and lactation." [2]

The thyroid gland is specially active in pregnancy and if the mother has been living on the margin of safety as regards iodine the gland may enlarge in an effort to perform its functions without an adequate supply. In the Goiter Belt, iodine should be given throughout

[2] Sherman, H. C. *Chemistry of Food and Nutrition*, 3d edition, page 502. The Macmillan Co. (1926).

pregnancy to prevent goiter in the baby as well as in the mother. Iodized table salt may be used, but administration of iodine in suitable form and dosage by a physician is preferable.

During pregnancy the mother must eliminate the waste products from the unborn child in addition to those from her own body, and it is important that this be facilitated by a relatively large proportion of liquids. At least 2 quarts of fluid should be taken daily. One quart should be milk and of the remainder a considerable part may well be fruit juice, or broths made with vegetable juices. When fresh milk is not available, milk powder or evaporated milk should take its place. The milk will insure protein of good quality. Meat should be used sparingly so that the total protein intake may not exceed 10 per cent of the total calories, lest the kidneys be overtaxed.

The diet will also need to be more laxative than usual. Liberal amounts of fresh fruits, and leafy vegetables, with whole wheat bread, bran breakfast foods, and bran bread are most desirable at this time, not only for laxative effect but for mineral salts and vitamins. Care should be taken in their selection to secure a liberal supply of vitamin C. In addition to a well-regulated diet, the prospective mother should spend several hours each day out of doors exposed to the sunshine. If the locality or the season makes this impossible, she should take cod-liver oil as a source of vitamin D. The diet of the pregnant woman cannot safely be left to chance. According to Mendenhall[1]

[1] Mendenhall, D. R. "Preventive Feeding for Mothers and Infants." *Journal of Home Economics*, Vol. 16, page 570 (1924).

many women at the beginning of pregnancy are in a state of undernutrition and may require a considerable increase in both energy-yielding and body-building and regulating foods.

The Nutrition of the Nursing Mother

When the baby is born, the demand upon the mother for nourishment does not cease; it merely takes another form, and continues to increase with the growth of the child. The secretion of the mammary gland is wonderfully adapted to the needs of the offspring. It is impossible to find an adequate substitute, and the work the baby has to do to get his food is advantageous in bringing a good supply of blood to the muscles of mouth, nose, and throat; in producing a well-formed arch for the roof of the mouth and well-developed jaws to hold the second teeth without overlapping and irregularity. It is also believed to help in the development of the abdominal muscles; at least breast-fed babies seem less likely to have protruding abdomens than the artificially fed. Every well-nourished mother with proper instruction should be able to nurse her baby.[1] But it is not to be expected that a mother may entirely overcome bad habits of diet throughout all her previous life in a few days or weeks after lactation has begun. In pregnancy, preparation for lactation begins and adequate nutrition throughout the gestation period should enable a mother to meet more successfully the strain of lactation.

[1] Helpful advice may be found in *Infant Care* by Mrs. Max West, Children's Bureau, United States Department of Labor, or in *Mother and Child* by C. U. Moore, J. B. Lippincott Co., 1923, if a physician is not available.

Whether there is a specific lactation factor in diet is not yet clear, but there is evidence from experiments with rats [1] that diets which are entirely adequate for growth and reproduction do not always support ideal lactation. According to Evans, fresh leaves or wheat embryo in large amount seem to improve lactation, and egg yolk and beef muscle appear to have a rather marked effect. Dried leaves have not produced the same results as fresh leaves. Inasmuch as egg yolk and fresh green vegetables should, for reasons already explained, enter into the diet of a nursing mother, it seems unlikely that any good diet constructed in accord with our present knowledge of dietary essentials, will lack those factors which promote good lactation.

Quantitatively, the demands on the mother grow greater day by day. A baby a week old may need only 16 ounces of milk in 24 hours, but three weeks later may be taking 28 or 30 ounces. Twenty-eight ounces of milk means about 560 calories. These must be secured from the food eaten by the mother, or else taken from the fuel reserves of her own body. Oftentimes mothers lose weight during the lactating period or fail to produce milk to full capacity because of insufficient food. It would seem reasonable to allow the mother in the first three months, as additional fuel for the milk supply, 60 calories per day for each pound of the baby's weight, in the second three months about 50 calories per pound, and for the next three months not less than 40 or 45 calories per pound.

[1] Evans, H. M. "Unique Dietary Needs for Lactation." *Science*, Vol. 60, pages 20–22 (1924).

To furnish the protein represented in the milk, there should be added to the mother's diet at least two protein calories for each protein calorie withdrawn in the milk.

The calcium requirement of a nursing mother supplying 30 ounces of milk per day is nearly twice as high as it is under ordinary conditions, and her phosphorus requirement is increased at least one-fourth. The needs for extra protein, calcium, and phosphorus are most efficiently met by the liberal use of milk.

The baby's need of vitamins must also be met by the mother's milk. It has been shown that the amount of any vitamin in milk depends directly upon the food, since vitamins are not manufactured in the mother's body. Even though vitamin A can be stored, it should be liberal in the diet, since it would be a distinct disadvantage to the mother to give up her reserves. Vitamins B and C need to be plentiful every day, since there will be little or no body store of either to draw upon. Vitamin D in mother's milk may be increased by irradiation of the mother with ultraviolet light.

The Baby

The normal child of a well-nourished mother, although requiring constant and intelligent care, should not be a nutritional problem. Nature provides the ideal nourishment in the secretion of the mammary gland, which in response to the sucking of the child, yields nutriment proportional to that demand. The vigorous child thus assures his own supply; the delicate child may be the victim of insufficient food because he

cannot "work his way" so well. To-day such infants are helped along by manual stimulation of the gland, whereby milk is furnished the baby and the supply is kept up until greater strength enables him to draw enough for his needs.

The most important considerations for the breast-fed baby are therefore:

(1) A well-nourished mother.
(2) Strength to draw milk as needed or help if strength is inadequate.
(3) Conditions of life which make it possible to digest the food eaten, and sunshine.
(4) Adequate rest, freedom of movement, fresh air, to insure the best use of food absorbed.

(1) A well-nourished mother must have not only the food required to maintain herself, but in addition the equivalent of the food material given to the baby as milk every day.

(2) The digestive tract of a baby is very delicate and has a great deal of work to do because of the relatively high food needs of this period of very rapid growth. An upset means loss of food that can ill be spared, and disturbance of the tract itself which may lead to irritability, acute indigestion or, if long continued, to chronic malnutrition. Regularity of meals is of prime importance. Intervals between meals must be neither too short nor too long. The milk will be more uniform in quality, and intervals of rest for the stomach aid appetite and digestion. A practical schedule is suggested on page 457, but a mother (especially with her first child) appreciates the advice of a physician skilled in the care of babies, and should

have it if possible either from a private physician or from a member of the staff of a baby health station or child welfare clinic. Every day is significant in a little baby's life, and expert supervision makes possible the finest adjustment of the daily program to the needs of the greatest individualist in the world—the baby.

(3) Without adequate rest growth is impossible. The newborn child sleeps the greater part of the twenty-four hours. At six months of age, it still sleeps sixteen to eighteen hours, and at the end of a year, about fourteen hours. When not sleeping, the very young baby should lie in a comfortable bed, free to move but not moved by some one else, except when feeding or change of clothing makes handling necessary. When the child is old enough to sit up, care must be taken to guard against overdoing the new accomplishment. At the least sign of fretting it may be well to lay the baby upon its bed. There is no better place to rest and no more comfortable place to cry.

Fresh air is the best of tonics and the necessity for sunshine has been pointed out in connection with the discussion of vitamin D and rickets in Chapter X. As an additional safeguard, the routine use of cod-liver oil in climates where the winter sunshine is irregular and not intense seems imperative. It may mean the difference between good teeth and bad, between a well-coördinated set of joints to promote good posture, and knock-knees, flat feet and other hindrances to easy standing and walking; or (for the girl) between a well-developed pelvis and easy maternity or a poorly developed one and perilous mother-

hood. There is nothing to lose and a chance of much to gain by its use.

Weaning the Breast-fed Baby

In the sixteenth century mothers were advised not to wean their children until they had all their teeth. To-day in the United States it is usually possible to wean a baby before it is a year old. By that time it is stronger, so that the inevitable differences between the best "artificial" diet and mother's milk need not be a serious obstacle to success. A very young baby is in danger of having his digestion upset by any food but his mother's milk. In case of misfortune, we must do the best we can, but it is usually best to give the baby the benefit of his mother's milk through the first nine months of his life.

This does not mean, however, that we are to let the baby subsist exclusively on his mother's milk for nine months and then abruptly change to other food. Such a course is fraught with peril if not disaster. Preparation for weaning should start some months beforehand, and the baby should gradually be accustomed to the foods which are to be his diet when weaning is fully accomplished. Since nursing babies are liable to rickets, it is well to begin cod-liver oil early, especially if the baby is born in the fall and must depend on a fickle sun for ultra-violet rays. At the age of three months, from one-half to one teaspoonful of cod-liver oil may be given once a day between two breast feedings and continued until long sun baths can be taken daily in a brilliant sunshine.

The next addition should reinforce the mother's milk

with regard to vitamin C since this in liberal amounts may be favorable to the development of the teeth, and may even protect against subacute scurvy if the mother's diet is not sufficiently rich in this dietary essential. For this purpose a teaspoonful of strained orange juice or tomato juice is most suitable, and may be introduced at the fourth month, between two breast feedings.

As the next step in training the baby to a mixed diet, a cooked cereal jelly is desirable. A teaspoonful or two, cooked very soft, strained, and seasoned lightly with salt, may be given at the time of a morning and evening feeding. The main object at this time being to establish the habit of eating cereals, regularity of feeding is more important than the quantity fed. When the habit is well established the quantity can easily be increased.

A further step in training the baby to other foods may be taken in the sixth month by adding a little cooked green vegetable juice (or juice and sifted pulp), at a feeding when cereal is not given. Preference should be given to those vegetables rich in iron, such as spinach, peas or carrots, and in this instance also a teaspoonful is sufficient for the first few weeks after vegetables are introduced into the diet, gradually increasing to a tablespoonful of sifted pulp.

When several teeth come, a crust of bread may be given at the conclusion of one feeding to start training in mastication. By the time these various steps have been taken, it will be possible to substitute cow's milk for one breast feeding and shortly thereafter to substitute a second feeding of cow's milk, after which complete weaning should be comparatively easy.

From the outset, regularity in the feeding schedule is of the greatest importance, as it not only helps to maintain a milk supply of uniform quality, but also assists in keeping the baby's digestive tract in good condition by suitable intervals of rest between meals. As a rule, intervals between meals should be not less than three hours, and after a baby is three months old (if not sooner) may be lengthened to four hours. Cool boiled water should be given regularly between feedings, as the baby's water needs are high. Whatever the schedule decided upon, it should be scrupulously adhered to just as long as it is in effect.

The night's rest of the mother should be broken as little as possible. Most babies are now trained to sleep from midnight to morning without nursing, and after the age of three months, the last feeding may be given at 10 P. M.

The characteristic changes in the feeding program from birth through weaning time are shown in the following schedule.

Schedule for Breast-fed Babies

First Month: Breast feedings at 6 and 10 A. M.; 1, 4, 7, 11 P. M.

After Third Month: Breast feeding at 6 and 10 A. M.; 2, 6, 10 P.M.

Third Month: Add 1/2 tsp. of cod-liver oil after one morning feeding. At fourth month increase to 1 tsp.

Fourth Month: Add 1 tsp. orange juice one hour before 10 A. M. breast feeding. Increase gradually to 2 tsp. by 5th month (tomato juice may be substituted).

Fifth Month: Add 1 tsp. cooked cereal at 10 A. M. feeding and 1 tsp. at 6 P. M. feeding. Increase gradually to 1 tbsp. at each feeding by 7th month.

Sixth Month: Add 1 tsp. vegetable juice (either spinach or carrots cooked in a very small amount of water) with 2 P. M. feeding. Increase gradually to 1 tbsp. by 8th month.

Eighth Month: Add crust of stale bread, zwieback or toast at 2 P. M. feeding.

Ninth Month: Use pulp of vegetables put through fine sieve along with juice. Add one or two new vegetables to list (peas, asparagus tips, tender string beans). Discontinue 10 P. M. feeding.

Tenth Month: Discontinue 2 P. M. breast feeding. Give 2 oz. of cow's milk over cereal at 10 A. M. and again at 6 P. M. For 2 P. M. meal give ¼ cup vegetable soup (milk, strained vegetable pulp, a little salt) baked potato with a little butter, 1 tbsp. lightly sweetened apple sauce and toast or zwieback. In middle of month substitute 6 oz. warm cow's milk for breast feeding at 10 A. M.

Eleventh Month: Substitute 6 oz. warm cow's milk for 6 P. M. breast feeding and in two weeks discontinue 6 A. M. breast feeding. When breast feeding is discontinued, arrange schedule as follows through 15th month.

7 A. M. 8 oz. milk to drink.

9 A. M. 2 tbsp. orange juice.

10 A. M. 2 tbsp. cooked cereal with 2 oz. of milk, 6 oz. milk to drink, toast.

2 P. M. ½ cup vegetable soup or milk and sifted vegetable pulp given separately, baked potato with butter, ½ yolk of egg, 1 tbsp. cooked fruit pulp, toast or zwieback.

6 P. M. 2 tbsp. cooked cereal, 2 oz. milk on cereal, 6 oz. warm milk to drink, toast and butter.

Artificial Feeding of Well Babies

No matter how strong our convictions as to the importance for the baby of breast feeding through the major portion of the first year, we cannot shut our eyes to the fact that circumstances may arise which make the substitution of some other form of nourishment imperative. It behooves us therefore to be prepared to deal intelligently with such emergencies.

In its essence, the problem of planning a diet for a baby is not very different from that of a diet for any growing child. There is the same need of an adequate supply of calories; of protein, with growth-sustaining amino acids; of an assortment of ash constituents and

vitamins each suitable in amount for rapid growth; and of a liberal supply of water. As shown in Chapter V, the total energy requirement during the first year of life is about 100 calories per kilogram of body weight, and as pointed out in Chapter VII, the protein needs of this period will be best met when from 10 to 15 per cent of the total calories (or at least one protein "share" for every calorie "share") are from proteins of the best quality. The relatively high requirements for mineral elements and vitamins have already been discussed in detail in Chapters IX and X and the daily program for the one-year-old child in Section 2 of this chapter.

The special problems of artificial feeding in infancy lie chiefly in making the diet sufficiently easy to digest. Any food but mother's milk is a risk in the stomach of the young baby. The selection of foods which will meet all the quantitative requirements, the arrangement of the feeding schedule, the way in which the meals are prepared and fed, in fact the whole daily régime of the baby must have the most careful consideration in every detail if the venture is to be successful. The younger the baby, the more difficult the task. Whenever any mother's milk is available it should be used, even if it is not enough and has to be supplemented by other food.

The best foundation for the artificially fed baby's diet is clean, fresh cow's milk of the best quality. An ounce and a half of milk per pound of the baby's weight will furnish the requisite protein and the major portion of the total calories. To this must be added some easily digested carbohydrate food, the best choice being milk sugar or some form of malt food (such as

dextri-maltose or a mixture of the two), rather than any sweeter sugar. From this the calories needed in addition to those furnished by the milk are derived.

Water must be added to the milk-carbohydrate mixture, because without it the food will be too hard for the baby to digest. It is a good rule to allow about 3 ounces of fluid per pound of baby for a child under 4 months of age, about 2½ ounces per pound for a baby 4 to 6 months old; and thereafter to decrease the amount of water gradually until in the latter part of the first year, undiluted milk can be taken safely. The water to be used may therefore be calculated by deducting from the total amount of food, the volume of milk used. Thus a baby weighing 16 pounds and needing 24 ounces of milk but 36 ounces of fluid should have 12 ounces of water added to the milk.

The milk-carbohydrate-water mixture must be prepared by careful measure each day, and divided equally among the feeding bottles which represent the number of feedings to be given in 24 hours. These bottles must be sterilized before using, and the food mixture should be quickly brought to the boiling point before putting it into the bottles. When the requisite amount of food has been put in, they should be stoppered with sterilized cotton and kept cool till needed. At feeding time, one bottle should be quickly warmed to body temperature and fed without delay.

The milk mixture (so-called modified milk) will need to be supplemented for vitamin C from the outset and very soon for iron. The need of vitamin D, or its equivalent in sunlight, will be at least as great in case of the artificially fed as of the breast-fed child. Provision for

these needs can be made in the same fashion as indicated for the breast-fed child, by daily use of orange juice or its equivalent for vitamin C; of green vegetables and egg yolk for iron; and of cod-liver oil for vitamin D.

The following schedule illustrates the application of these principles. The foods are given in quantities for 24 hours, and in addition to the number of feedings the total amount of fluid for each feeding is stated in ounces. This plan provides for regularity of meals; careful graduations to suit the child at different stages of his rapid growth; gradual reduction of water so that as more milk is needed the total volume shall at no time overtax the stomach; and enough fruit juice and vegetable pulp to meet the baby's requirements according to his age with very little danger of being too laxative. If there should be a tendency to constipation a little prune juice may be mixed with the orange juice, or the amount of vegetable pulp very cautiously increased. The best way to determine whether the total calories are sufficient is by weekly weighing of the baby and study of the whole weight record to see whether good progress is made. If a baby does not gain at a normal rate, a systematic search should be made to find the cause. Every mother should have at least one handbook on child care[1] and should secure advice from a physician expert in the care of babies, either privately or at a baby health station or other health center unless so situated that neither is accessible. It pays to take the best possible care to start the baby

[1] *Infant Care*, published by the Children's Bureau and furnished free on request, has already been mentioned in Section 2. Holt's *Care and Feeding of Children*, published by D. Appleton and Company, 1926, has helped many mothers who could not secure individual help.

right, and foster from the beginning those habits which promote health and vigor. The reward will come partly in the present, in a healthy, happy baby which is a delight instead of a worry, but more in the future when to the grown man or woman, the full reward comes in the enjoyment of a vigorous adult life and deferred old age.

Schedule for Artificial Feeding of Well Babies Based on Average Weight for Age in Quantities for 24 Hours

Age	No. Feedings	Amount per Feeding, oz.	Whole Milk, oz.	Water, oz.	Milk Sugar[1]	Orange Juice	Cereal Jelly	Stale Bread, Toast or Zwieback	Green Vegetable Pulp	Egg Yolk
Days										
1 & 2	6	½	1	2	½ tsp.					
3 & 4	6	1	2	4	2 tsp.					
5, 6, 7	6	2½	5	10	1 tbsp.					
8–14	6	3⅓	8	12	1 "					
Weeks										
2–4	6	4	9	15	1 "					
Months (beginning of)										
2	6	4⅓	10	16	1 tbsp.					
3	5	5½	13	15	1¼ "					
4	5	6	17	13	1½ "	1 tsp.			1 tsp.	
5	5	6½	21	12	1½ "	2 "			2 "	
6	5	7	23	12	1½ "	1 tbsp.	2 tsp.	small piece	1 tbsp.	
7	5	7	25	10	1½ "	2 "	2 tbsp.	1 slice	1 "	
8	5	7	26	9	1½ "	2 "	2 "	1 "	2 "	tsp. 1 "
9	5	7	27	8	1½ "	2 "	3 "	1 "	2 "	1 "
10	5	7	28	7	1½ "	3 "	3 "	1 "	2 "	1 "
11	5	7	29	6	1 "	3 "	4 "	1 "	3 "	1 "
12	5	7	30	5	1 "	3 "	4 "	1 "	3 "	1 "

[1] Dextrimaltose may be substituted wholly or in part and is better digested by some babies. It is a little lighter than milk sugar, hence in using it, increase the quantities in the proportion of one teaspoonful for each tablespoonful in the schedule.

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APPENDIX

TABLE I

SHARES OF PROTEIN, CALCIUM, PHOSPHORUS, AND IRON CARRIED BY ONE ENERGY SHARE OF EDIBLE FOOD MATERIAL AND RELATIVE AMOUNTS OF VITAMINS A, B, AND C

1 Energy Share = 100 calories
1 Calcium Share = 0.023 gram
1 Iron Share = 0.0005 gram
1 Protein Share = 2.5 grams or 10 calories
1 Phosphorus Share = 0.044 gram

+ indicates that the food contains the vitamin.
++ indicates that the food is a good source of the vitamin.
+++ indicates that the food is an excellent source of the vitamin.
— indicates that the food contains no appreciable amount of the vitamin.
? indicates doubt as to presence or relative amount.

Food Material	Weight gms.	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamins		
						A	B	C
Almonds	15.5	1.29	1.61	1.64	1.20	+	++	?
Apples	159.0	0.26	0.52	0.45	0.96	+	+	++
Apricots	36.0	0.76	1.00	1.00	1.04	?	?	?
Asparagus	450.5	3.24	5.34	4.02	9.02	?	+++	?
Bananas	101.4	0.53	0.39	0.70	1.22	+	+	++
Beans, dried, navy	29.0	2.61	2.04	3.11	4.06	+	+++	?
" " kidney	28.8	2.33	1.74	3.25	4.32	+	+++	?
" " Lima	28.6	2.32	0.87	2.13	4.00	?	?	?
" string	241.0	2.22	4.78	2.86	5.30	++	++	++
Beef, lean round	13.6	5.45	0.37	3.32	3.08	+	++	—
Beets	217.1	1.39	2.78	1.91	2.60	+	+	+

Table 1—Shares per 100 Calories

Food Material	Weight gms.	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamins A	Vitamins B	Vitamins C
Blackberries	173.0	0.90	1.26	1.32	2.08	?	?	?
Blueberries	135.0	0.32	1.17	0.25	2.40	?	?	?
Bread, Boston brown	44.2	1.05	2.44	1.86	2.60	+	++	—
" "entire" wheat [1]	40.1	1.52	0.31	1.31	1.20	+	++	?
" " " [2]	34.9	1.53	1.10	1.53	1.20	++	++	—
" graham	38.4	1.37	0.87	1.91	1.92	+	++	—
" rye	39.3	1.42	0.39	1.32	0.78	+	++	—
" white [1]	39.0	1.56	0.22	.53	0.51	?	+	—
" " [2]	32.7	1.41	0.89	0.72	0.50	+	+	—
" " [3]	39.0	1.40	0.48	0.80	0.70	?	+	—
Brussels sprouts	487.8	2.92	3.74	8.63	6.98	+	++	+(cooked)
Buckwheat flour	28.7	0.74	0.48	1.48	0.68	—	—?	—
Butter	13.0	0.05	0.09	0.05	0.06	+++	—	—
Buttermilk	279.6	3.36	12.82	6.16	1.40	+	++	+?
Cabbage	317.5	2.03	6.22	2.09	6.98	+	++	+++(raw
Cantaloupe	252.5	0.60	1.91	0.86	1.42	++	++	?
Carrots	221.2	0.97	5.39	2.29	2.66	+++	++	++(raw)
Cauliflower	327.9	2.36	17.52	4.54	3.94	+	++	+
Celery	540.6	0.51	18.30	4.57	5.40	—	++	?
Chard	262.0	3.35	17.09	2.38	13.10	++	+	?
Cheese, American	22.8	2.60	9.22	3.54	0.60	++	—?	?
Cherries	128.2	0.48	1.09	0.88	1.02	?	?	?
Chestnuts	41.3	1.02	0.61	1.00	0.58	?	+	?

[1] Made with water.
[2] Made with milk.
[3] With a little milk.

Table 1—Shares per 100 Calories

Food Material	Weight gms.	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamins A	Vitamins B	Vitamins C
Chicken, broilers	19.9	7.96	0.52	4.88	6.30	?	?	?
Chocolate, unsweetened	16.4	0.84	0.65	1.71	0.88	?	?	?
Clams, long	194.6	7.93	12.39	6.41	19.40	?	?	?
" round	215.5	5.60	9.96	2.27	19.40	?	?	?
Cocoa	20.1	1.74	1.00	3.25	1.08	?	?	?
Coconut	16.9	0.38	0.26	0.41	0.60	+	++	?
Cod steak	21.6	8.62	1.03	5.64	2.37	?	?	?
Corn, canned	102.0	1.22	0.26	2.31	1.58	+	++	?
Cornmeal	28.1	1.04	0.22	1.20	0.60	–	–	–
Crackers, soda	24.2	0.95	0.26	0.57	0.72	–	–	–
Cranberries	214.6	0.34	1.70	0.61	2.58	?	?	+
Cream, 18% fat	51.4	0.51	2.17	1.00	0.20	+++	++	?
" 40% fat	26.3	0.23	0.87	0.45	0.10	+++	++	?
Cucumbers	574.8	1.84	3.91	4.34	2.30	–	+	+
Currants, dried	31.1	0.30	1.13	1.39	1.74	?	?	?
" fresh	174.8	1.05	1.96	1.50	1.74	?	?	?
Dandelion greens	163.9	1.57	7.48	2.66	8.80	++	++	+
Dates	38.8	0.24	0.83	0.36	1.72	?	?	?
Eggplant	358.4	1.72	1.78	2.77	3.68	+	+	?
Eggs	67.5	3.62	1.96	2.77	4.10	+++	+	–
Egg, white	196.1	9.65	0.87	0.50	0.40	–	?	–
" yolk	27.6	1.73	1.56	2.68	4.60	+++	++	–
Farina, white	27.6	1.22	0.26	0.80	0.44	–	–?	–
" dark	27.6	1.45	0.56	2.68	2.80	+	++	–

Table 1—Shares per 100 Calories

Food Material	Weight gms.	Protein Shares	Calcium Shares	Phos-phorus Shares	Iron Shares	Vitamins		
						A	B	C
Figs	31.6	0.54	2.21	0.84	1.90	?	?	?
Flour, buckwheat	28.7	0.74	0.48	1.48	0.68	–	–?	–
" "entire" wheat	27.8	1.54	0.39	1.50	1.40	+	++	–
" graham	27.9	1.48	0.48	2.29	2.00	+	++	–
" white (wheat)	28.3	1.28	0.26	0.59	0.46	–	–?	–
" rye	28.5	0.78	0.22	1.86	0.74	–	+	–
Grapefruit	212.8	0.46	1.73	0.82	1.16	+	++	+++
Grapes	103.7	0.54	0.83	0.73	0.62	+	+	+
Grape juice	100.0	0.14	0.48	0.25	0.60	+	+	+?
Halibut steak	15.3	6.14	0.72	3.57	1.68	?	?	?
Ham, lean smoked	7.4	2.97	0.19	2.02	2.20	–	++	–
Hazelnuts	14.2	0.90	1.78	1.14	1.14	?	?	?
Herring	13.7	5.50	0.64	2.57	1.51	?	?	?
Hominy	28.3	0.93	0.09	0.61	0.50	–	–?	–
Honey	30.6	0.05	0.09	0.14	0.60	–	+?	–
Huckleberries	135.0	0.33	1.17	0.25	2.40	?	?	?
Kale	434.8	5.91	40.08	5.93	26.09	?	?	?
Kohl-rabi	225.7	2.59	10.83	4.23	3.88	–	–	+
Lamb, breast	6.6	2.64	0.18	1.65	2.00	+	++	–
" chop, broiled	6.3	2.52	0.15	1.60	1.83	+	++	–
Lemons	323.6	0.90	3.52	1.11	2.70	+	++	+++
Lentils	28.7	2.95	1.35	2.86	4.94	+	++	–?
Lettuce	523.6	2.51	9.74	5.09	7.34	+	++	+++
Liver, beef	15.8	6.30	0.40	3.88	12.57	+++	++	+

Table 1—Shares per 100 Calories

Food Materials	Weight gms.	Protien Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamins A	Vitamins B	Vitamins C
Macaroni	28.0	1.48	0.26	0.91	0.66	—	—?	—
Maple syrup	35.0	0.00	1.61	0.07	2.00	?	?	?
Milk, whole	144.5	1.90	7.56	3.05	0.70	+++	++	+?
" skimmed	272.5	3.70	14.39	5.95	1.36	+	++	+?
" condensed, sweetened	30.6	1.08	4.18	1.64	0.40	+++	++	+?
" " unsweetened	59.9	2.30	8.22	3.32	0.80	+++	++	—?
Molasses	34.9	0.33	3.22	0.34	5.10	—	+	?
Muskmelon	252.5	0.60	1.87	0.86	1.60	++	++	?
Mutton, leg	10.4	4.15	0.28	2.54	3.12	—?	++	?
Oatmeal	25.2	1.68	0.74	2.25	1.92	—?	++	—
Olives	33.4	0.15	1.78	0.09	1.94	?	?	?
Onions	205.4	1.32	3.00	2.11	2.00	—?	+	++
Oranges	194.6	0.62	3.83	0.91	0.78	+	++	+++
Orange juice	231.5	0.56	2.91	0.84	0.92	+	++	+++
Oysters	204.5	4.92	4.61	6.95	17.86	?	?	+
Parsnips	154.1	0.99	3.96	2.66	1.80	—?	++	?
Peaches	242.1	0.68	1.65	1.30	1.46	+	+	++
Peanuts	18.2	1.88	0.57	1.66	0.72	+	++	?
Pears	158.0	0.38	1.04	0.93	0.94	?	+	?
Peas	99.9	2.77	1.13	2.90	3.30	++	++	++ (can'd)
Pecans	13.6	0.52	0.52	1.02	0.70	+	+	?
Peppers, green	386.1	1.84	1.48	3.30	4.44	++	++	++
Pineapple, fresh	232.0	0.37	1.78	1.45	2.32	++	++	++
Plums	118.5	0.48	1.04	0.86	1.18	?	?	?
Pork, loin chop	8.1	3.20	0.20	1.97	1.20	—?	++	—
Potatoes, white	120.0	1.06	0.69	1.57	3.12	+	++	++ (cooked 15 minutes)

Table 1—Shares per 100 Calories

Food Material	Weight gms.	Protein Shares	Calcium Shares	Phosphorus Shares	Iron Shares	Vitamins A	Vitamins B	Vitamins C
Potatoes, sweet	81.2	0.58	0.69	0.84	0.82	++	++	++
Prunes	33.2	0.28	0.78	0.80	2.00	++	++	−
Pumpkins	389.1	1.56	3.87	5.20	2.60	+	+	+
Radishes	341.3	1.77	3.17	2.23	4.10	−	+	?
Raisins	29.0	0.30	0.83	0.86	2.78	−	+	−
Raspberries	151.1	1.03	3.22	1.77	1.82	?	?	++
Rhubarb	433.0	1.04	8.22	3.05	8.66	?	?	+
Rice, brown	28.5	1.01	0.14	1.36	1.16	+	++	−
" white	28.5	0.91	0.05	0.61	0.52	−	−	−
Rutabagas	350.9	1.26	8.04	3.18	2.55	−	++	+++
Salmon, fresh	10.8	4.33	0.49	2.82	1.19	+	?	?
Shredded wheat	27.4	1.40	0.48	2.02	2.46	+	++	−
Spinach	418.4	3.51	12.22	6.48	30.12	+++	+++	+ (cooked)
Squash, summer	216.9	1.21	1.71	0.80	2.60	?	?	?
" winter	216.9	1.24	1.74	1.39	2.60	++	?	?
Strawberries	256.4	1.02	4.55	1.64	4.10	?	+	+
Tapioca	28.2	0.04	0.18	0.57	0.90	−	−	−
Tomatoes, canned	442.5	1.58	2.17	2.57	3.50	++	++	+++
Tuna fish	17.6	7.02	0.82	4.56	1.94	?	?	?
Turnips	253.8	1.32	7.00	2.66	2.55	−	++	++
Veal, lean breast	13.50	5.40	0.37	3.24	3.92	−	+?	?
" lean leg	17.5	6.98	0.44	4.28	2.70	−	+?	?
Walnuts, English	14.2	1.04	0.56	0.34	0.60	+	++	?
Watermelon	331.1	0.53	1.65	0.23	1.98	?	?	?

TABLE II

Shares of Energy, Protein, Calcium, Phosphorus, and Iron Yielded by Common Measures of Food Materials[1]

Material	Approximate Measure	Weight		Shares Contributed to the Diet				
		Oz.	Gms.	Calories	Protein	Calcium	Phosphorus	Iron
Almonds, chopped	1 cup	3.0	85	5.9	7.6	9.4	9.6	7.0
" shelled	10 nuts	0.3	10	0.6	0.8	1.0	1.0	0.7
Apples (A. P.)[2]	1 medium	6.0	170	0.8	0.2	0.4	0.4	0.8
Banana	1 large	5.5	156	1.0	0.5	0.4	0.7	1.2
Beans, Lima, dried	1 cup	5.5	156	5.4	12.6	4.7	11.5	21.6
" navy, dried	1 cup	7.0	198	6.8	17.9	14.0	21.3	27.8
" string, fresh	3/4 cup	3.3	96	0.4	0.8	1.9	1.1	2.1
Beef, lean round " " "	3/4 in. slice 2 1/2 in. square	4.0	113	1.5	8.2	0.5	5.0	4.6
Bread, white, water	1 slice 1/2 in. thick	0.7	20	0.5	0.8	0.1	0.3	0.3
" whole wheat, water	1 slice 1/2 in. thick	1.1	32	0.8	1.2	0.3	1.0	0.9
Butter	1 tbsp.	0.5	14	1.1	0.1	0.1	0.1	0.1
"	1 cup	8.0	227	17.4	0.9	1.6	0.9	1.1
Buttermilk	1 cup	8.5	241	0.9	3.0	11.3	5.4	1.2
Cabbage, shredded	3/4 cup	2.3	64	0.2	0.4	1.2	0.4	1.4
Carrots, diced	3/4 cup	3.5	111	0.5	0.5	2.7	1.1	1.3
Celery, 1/4 in. pieces	1 cup	4.5	128	0.2	0.1	4.4	1.1	1.3
Cheese, American	1 1/8 in. cube	1.6	46	1.0	2.6	9.2	3.5	0.6
" grated, dry	1 tbsp.	0.2	4	0.2	0.4	1.5	0.6	0.1
" " fresh	1 tbsp.	0.3	7	0.3	0.8	2.9	1.1	0.2
Chocolate, unsweetened	1 tbsp.	0.2	5	0.3	0.2	0.2	0.5	0.3
" "	1 square	1.0	28	1.7	1.5	1.1	3.0	1.5

[1] Based on edible portions unless otherwise indicated. [2] As purchased.

Table II—Shares in Common Measures

Material	Approximate Measure	Weight		Shares Contributed to the Diet				
		Oz.	Gms.	Calories	Protein	Calcium	Phosphorus	Iron
Cocoa	1 tbsp.	0.3	7	0.4	0.6	0.4	1.1	0.4
Coconut, shredded	1 cup	2.8	79	5.4	2.0	1.4	2.2	3.2
Cod-liver oil	1 tbsp.	0.4	11	1.0	0.0	0.0	0.0	0.0
Cottonseed oil	1 tbsp.	0.4	11	1.0	0.0	0.0	0.0	0.0
Condensed milk, sweetened	1 tbsp.	0.7	19	0.6	0.7	2.7	1.1	0.3
" " "	1 cup	11.0	312	10.2	11.0	42.5	16.7	4.1
" " unsweetened	1 tbsp.	0.6	17	0.3	0.6	2.2	0.9	0.2
" " "	1 cup	8.0	227	3.8	8.7	31.0	12.5	3.0
Corn, canned	1 cup	9.0	255	2.6	3.1	0.7	5.9	4.0
Cornmeal	1 cup	5.0	142	5.0	5.2	1.1	6.1	3.0
Cornstarch	1 tbsp.	0.3	9	0.3	0.0	0.0	0.0	0.0
Cracker, crumbs	1 tbsp.	0.3	8	0.3	0.3	0.1	0.2	0.2
Crackers, soda	1 cracker	0.2	6	0.2	0.2	0.0	0.1	0.1
Cranberries, fresh	1 cup	3.5	99	0.5	0.2	0.8	0.3	1.2
Cream, 18% fat	1 tbsp.	0.5	14	0.3	0.1	0.6	0.3	0.1
" " "	1 cup	8.0	227	4.4	2.2	9.6	4.4	0.9
" 40% fat	1 tbsp.	0.7	19	0.7	0.2	0.6	0.3	0.1
" " "	1 cup	7.8	220	8.4	1.9	7.3	3.8	0.8
Dates, stoned	1 cup	6.2	176	6.1	1.5	5.1	2.2	10.5
" "	10 dates	2.5	70	2.5	0.6	2.1	0.9	4.3
Egg, whole (A. P.)	1 egg	2.5	71	0.7	2.5	1.4	1.9	2.9
" white	1 white	1.0	28	0.1	1.4	0.1	0.1	0.1
" yolk	1 yolk	0.6	17	0.6	1.0	0.9	1.5	2.6
Farina, light	1 cup	6.0	170	6.2	7.5	1.6	4.9	2.7

Table II—Shares in Common Measures

Material	Approximate Measure	Weight		Shares Contributed to the Diet				
		Oz.	Gms.	Calories	Protein	Calcium	Phosphorus	Iron
Farina, dark	1 cup	6.0	170	6.1	8.9	3.4	16.4	17.2
Figs, dried	1 cup	5.6	159	5.1	2.7	11.2	4.3	9.6
" "	2 medium	1.1	32	1.0	0.5	2.2	0.8	1.9
Flour, graham	1 tbsp.	0.3	9	0.3	0.5	0.2	0.8	0.7
" "	1 cup	5.0	142	5.0	7.5	2.4	11.6	10.2
" rye	1 tbsp.	0.3	9	0.3	0.3	0.1	0.6	0.2
" "	1 cup	5.0	142	5.0	3.9	1.1	9.2	3.7
" wheat, white, sifted	1 tbsp.	0.3	7	0.3	0.4	0.1	0.2	0.1
" " " "	1 cup	4.0	113	4.0	5.1	1.0	2.3	1.8
Gelatin, granulated	1 tbsp.	0.3	10	0.4	3.6	0.0	0.0	0.0
Grapefruit (E. P.)	1 medium	11.2	318	1.5	0.7	2.6	1.2	1.7
Grapes, Malaga	10 grapes	1.8	51	0.5	0.3	0.4	0.4	0.3
Grape juice	1 cup	7.0	198	3.0	0.4	1.4	0.8	1.8
Hominy grits	1 cup	5.5	156	5.5	5.1	0.5	3.4	2.8
Lard	1 tbsp.	0.5	14	1.2	0.0	0.0	0.0	0.0
"	1 cup	8.0	227	19.1	0.0	0.0	0.0	0.0
Lemon juice	1 tbsp.	0.5	14	0.1	0.0	0.0	0.0	0.0
Liver	3x3x3/4 in.	4.0	113	1.5	10.1	0.6	6.2	7.5
Macaroni, 1-in. pieces	1 cup	3.5	99	3.6	5.3	0.9	3.2	2.3
Milk, skimmed	1 tbsp.	0.7	20	0.1	0.3	1.0	0.4	0.1
" "	1 cup	8.5	241	0.9	3.3	12.7	5.2	1.2
" "	1 quart	34.0	964	3.6	13.3	51.5	21.3	4.9
" whole	1 tbsp.	0.7	20	0.1	0.3	1.1	0.4	0.1
" "	1 cup	8.5	241	1.7	3.2	12.9	5.2	1.2

Table II—Shares in Common Measures

Material	Approximate Measure	Weight		Shares Contributed to the Diet				
		Oz.	Gms.	Calories	Protein	Calcium	Phosphorus	Iron
Milk, whole	1 quart	34.0	964	6.8	12.9	51.3	20.7	4.8
Molasses, cane	1 tbsp.	0.8	23	0.7	0.2	2.1	0.2	3.3
" "	1 cup	12.0	340	9.8	3.2	31.4	3.3	49.8
Oats, rolled	1 cup	2.5	71	2.8	4.7	2.1	6.3	5.4
Olive oil	1 tbsp.	0.4	11	1.0	0.0	0.0	0.0	0.0
Onions (A. P.)	1 medium	2.7	76	0.3	0.4	0.9	0.6	0.6
Orange juice	1 tbsp.	0.5	14	0.1	0.0	0.2	0.0	0.1
" "	1 cup	8.0	227	1.0	0.6	3.0	0.9	1.0
Oranges (A. P.)	1 medium	7.6	214	0.8	0.5	3.1	0.7	0.6
Peaches, fresh (A. P.)	1 medium	3.5	100	0.3	0.2	0.5	0.4	0.4
Peanuts, shelled	1 cup	4.3	123	6.6	12.5	3.8	11.0	4.8
" "	10 nuts	0.3	9	0.5	0.9	0.3	0.8	0.4
Peanut butter	1 tbsp.	0.7	18	1.0	1.9	0.6	1.7	0.7
Pears, fresh (A. P.)	1 medium	3.2	90	0.5	0.2	0.5	0.5	0.5
Peas, canned	1 cup	6.0	170	1.3	3.7	1.5	3.7	4.4
" dried	1 cup	7.5	213	6.8	18.8	7.7	18.6	22.4
Pecans, shelled	1 cup	5.5	156	11.5	6.0	6.0	11.7	8.0
" "	10 nuts	0.4	12	0.8	0.4	0.4	0.8	0.6
Pineapple, fresh diced	1 cup	8.5	241	3.7	1.4	6.6	5.4	8.6
Potato, white	1 medium	5.2	150	1.0	1.1	0.7	1.6	3.2
" sweet	1 medium	7.2	206	2.5	1.5	1.7	2.1	2.1
Prunes	4 medium	1.2	33	1.0	0.3	0.8	0.8	2.0
Raisins	1 cup	5.0	142	4.9	1.5	4.1	4.2	13.6
Rhubarb, fresh 1-in. pieces	1 cup	4.0	113	0.3	0.3	2.1	0.8	2.3

Table II—Shares in Common Measures

Material	Approximate Measure	Weight		Shares Contributed to the Diet				
		Oz.	Gms.	Calories	Protein	Calcium	Phosphorus	Iron
Rice, white	1 tbsp.	0.5	14	0.5	0.5	0.0	0.3	0.3
" "	1 cup	7.0	198	7.0	6.3	0.4	4.3	3.6
Shredded wheat	1 biscuit	1.0	27	1.0	1.4	0.5	2.0	2.5
Spinach, steamed	1 cup	8.5	241	0.4	1.5	5.3	2.8	13.0
Squash, Hubbard, steamed	1 cup	7.8	220	1.1	1.4	1.9	1.5	2.9
Suet	1 cup	3.5	99	7.5	0.0	0.0	0.0	0.0
Sugar, granulated	1 tbsp.	0.5	14	0.5	0.0	0.0	0.0	0.0
" "	1 cup	7.4	210	8.4	0.0	0.0	0.0	0.0
Tapicoa	1 tbsp.	0.5	14	0.5	0.0	0.1	0.3	0.4
"	1 cup	6.5	184	6.4	0.3	1.2	3.7	5.8
Tomatoes, canned	1 cup	9.0	255	0.6	0.9	1.2	1.5	2.0
Turnips, ½ in. cubes	1 cup	4.8	135	0.5	0.7	3.6	1.4	1.3
Walnuts, English	1 cup	3.0	85	6.0	6.2	3.4	2.0	3.6
" "	10 nuts	1.8	50	3.5	3.6	2.0	1.2	2.1
Wheat, flaked	1 cup	3.0	85	3.1	4.5	1.7	8.3	8.7

TABLE III

Weight—Height—Age Table for Boys from Birth to School Age.[1]

Height (Inches)	Average Weight for Height (Pounds)	1 mo.	3 mos.	6 mos.	9 mos.	12 mos.	18 mos.	24 mos.	30 mos.	36 mos.	48 mos.	60 mos.	72 mos.
20	8	8											
21	9½	9	10										
22	10½	10	11										
23	12	11	12	13									
24	13½	12	13	14									
25	15	13	14	15	16								
26	16½		15	17	17	18							
27	18		16	18	18	19							
28	19½			19	19	20	20						
29	20½			20	21	21	21						
30	22			22	22	22	22	22					
31	23				23	23	23	23	24				
32	24½				24	24	24	25	25				
33	26					26	26	26	26	26			
34	27						27	27	27	27			
35	29½						29	29	29	29	29		
36	31							30	31	31	31		
37	32							32	32	32	32	32	
38	33½								33	33	33	34	
39	35								35	35	35	35	
40	36½									36	36	36	36
41	38										38	38	38
42	39½										39	39	39
43	41½										41	41	41
44	43½											43	43
45	45½											45	45
46	48												48
47	50												50
48	52½												52
49	55												55

Weight is stated to the nearest pound; height to the nearest inch; age to the nearest month.

Up to and including 34 inches the *weights are net.* Above this the following amounts have been added for clothing (shoes, coats and sweaters are not included):

35 to 39 in. $1^1/_4$ pounds   40 to 44 in. $1^1/_2$ pounds   45 to 49 in. $1^3/_4$ pounds

[1] Prepared by Robert M. Woodbury, Ph. D. Reprinted by permission of the American Child Health Association, 370 Seventh Avenue, New York City.

TABLE IV

Weight—Height—Age Table for Girls from Birth to School Age[1]

Height (Inches)	Average Weight for Height (Pounds)	1 mo.	3 mos.	6 mos.	9 mos.	12 mos.	18 mos.	24 mos.	30 mos.	36 mos.	48 mos.	60 mos.	72 mos.
20	8	8											
21	9	9	10										
22	10½	10	11										
23	12	11	12	13									
24	13½	12	13	14	14								
25	15	13	14	15	15								
26	16½		15	16	17	17							
27	17½		16	17	18	18							
28	19			19	19	19	19						
29	20			19	20	20	20						
30	21½			21	21	21	21	21					
31	22½				22	22	23	23	23				
32	24					23	24	24	24	25			
33	25						25	25	25	26			
34	26½						26	26	26	27			
35	29						29	29	29	29	29		
36	30							30	30	30	30	31	
37	31½							31	31	31	31	32	
38	32½								33	33	33	33	
39	34								34	34	34	34	34
40	35½									35	36	36	36
41	37½										37	37	37
42	39										39	39	39
43	41										40	41	41
44	42½											42	42
45	45												45
46	47½												47
47	50												50
48	52½												52

Weight is stated to the nearest pound; height to the nearest inch; age to the nearest month.

Up to and including 34 inches the *weights are net.* Above this the following amounts have been added for clothing (shoes and sweaters are not included):

35 to 39 in. 1 pound   40 to 44 in. 1½ pounds   45 to 49 in. 1¾ pounds

[1] Prepared by Robert M. Woodbury, Ph. D. Reprinted by permission of the American Child Health Association, 370 Seventh Avenue, New York City.

TABLE V

Weight—Height—Age Table for Boys of School Age

Height (Inches)	Average Weight for Height (lbs.)	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	11 Years	12 Years	13 Years	14 Years	15 Years	16 Years	17 Years	18 Years	19 Years	Height (Inches)
38	34	34	34*														38
39	35	35	35														39
40	36	36	36*														40
41	38	38	38	38*													41
42	39	39	39	39*	39*												42
43	41	41	41	41*	41*												43
44	44	44	44	44	44*												44
45	46	46	46	46	46*	46*											45
46	48	47*	48	48	48	48*											46
47	50	49*	50	50	50	50*	50*										47
48	53		52	53	53	53	53*										48
49	55		55	55	55	55	55	55*									49
50	58		57*	58	58	58	58	58*	58*								50
51	61			61	61	61	61	61	61*								51
52	64			63	64	64	64	64	64	64*							52
53	68			66*	67	67	67	67	68	68*							53
54	71				70	70	70	70	71	71	72*						54
55	74				72*	72	73	73	74	74	74*						55
56	78				75*	76	77	77	77	78	78	80*					56
57	82					79*	80	81	81	82	83	83*					57
58	85					83*	84	84	85	85	86	87					58
59	89						87	88	89	89	90	90	90				59

60	94							91*	92	92	93	94	95	96			60
61	99								95	96	97	99	100	103	106*		61
62	104								100*	101	102	103	104	107	111	116*	62
63	111								105*	106	107	108	110	113	118	123	63
64	117									109	111	113	115	117	121	126	64
65	123									114*	117	118	120	122	127	131	65
66	129										119	122	125	128	132	136	66
67	133										124*	128	130	134	136	139	67
68	139											134	134	137	141	143	68
69	144											137	139	143	146	149	69
70	147											143	144	145	148	151	70
71	152											148*	150	151	152	154	71
72	157												153	155	156	158	72
73	163												157*	160	162	164	73
74	169												160*	164	168	170	74

Age—years		6	7	8	9	10	11	12	13	14	15	16	17	18	19	
Average height (inches)	Short	43	45	47	49	51	53	54	56	58	60	62	64	65	65	
	Medium	46	48	50	52	54	56	58	60	63	65	67	68	69	69	
	Tall	49	51	53	55	57	59	61	64	67	70	72	72	73	73	
Average annual gain(lbs.).	Short	3	4	5	5	5	4	8	9	11	14	13	7	3		
	Medium	4	5	6	6	6	7	9	11	15	11	8	4	3		
	Tall	5	7	7	7	7	8	12	16	11	9	7	3	4		

In order to extend the range of the tables so as to include weights of children who are taller or shorter than those in these groups there have been added as starred figures estimated weights. All the other weights represent averages for each inch in height and age of the children observed in this study.

Prepared by Bird T. Baldwin, Ph. D., Iowa Child Welfare Research Station, State University of Iowa, and Thomas D. Wood, M. D., Columbia University, New York City. Reprinted by permission of the American Child Health Association, 370 Seventh Avenue, New York City.

TABLE VI

Weight—Height—Age Table for Girls of School Age

Height (Inches)	Average Weight for Height (lbs.)	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	11 Years	12 Years	13 Years	14 Years	15 Years	16 Years	17 Years	18 Years	Height (Inches)
38	33	33	33													38
39	34	34	34													39
40	36	36	36	36*												40
41	37	37	37	37*												41
42	39	39	39	39*												42
43	41	41	41	41	41*											43
44	42	42	42	42	42*											44
45	45	45	45	45	45	45*										45
46	47	47*	47	47	48	48*										46
47	50	49*	50	50	50	50	50*									47
48	52		52	52	52	52	53*	53*								48
49	55		54	54	55	55	56	56*								49
50	58		56*	56	57	58	59	61	62*							50
51	61			59	60	61	61	63	65							51
52	64			63*	64	64	64	65	67							52
53	68			66*	67	67	68	68	69	71*						53
54	71				69	70	70	71	71	73*						54
55	75				72*	74	74	74	75	77	78*					55
56	79					76	78	78	79	81	83*					56
57	84					80*	82	82	82	84	88	92*				57
58	89						84	86	86	88	93	96*	101*			58
59	95						87	90	90	92	96	100	103*	104		59

60	101						91*	95	95	97	101	105	108	109	111*	60
61	108							99	100	101	105	108	112	113	116	61
62	114							104*	105	106	109	113	115	117	118	62
63	118								110	110	112	116	117	119	120	63
64	121								114*	115	117	119	120	122	123	64
65	125								118*	120	121	122	123	125	126	65
66	129									124	124	125	128	129	130	66
67	133									128*	130	1 1	133	133	135	67
68	138									131*	133	135	136	138	138	68
69	142										135*	137*	138*	140*	142*	69
70	144										136*	138*	140*	142*	144*	70
71	145										138*	140*	142*	144*	145*	71

Age–Years		6	7	8	9	10	11	2	13	14	15	16	17	18	
Average height (inches)	Short	43	45	47	49	50	52	54	57	59	60	61	61	61	
	Medium	45	47	50	52	54	56	58	60	62	63	64	64	64	
	Tall	47	50	53	55	57	59	62	64	66	66	67	67	67	
Average annual gain (lbs.)	Short	4	4	4	5	6	6	10	13	10	7	2	1		
	Medium	5	5	6	7	8	10	13	10	6	4	3	1		
	Tall	6	8	8	9	11	13	9	8	4	4	1	1		

In order to extend the range of the tables so as to include weights of children who are taller or shorter than those in these groups there have been added as starred figures estimated weights. All the other weights represent averages for each inch in height and age of the children observed in this study.

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TABLE VII

Table of Weight and Height for Men at Different Ages[1]

Height	19 yrs.	20	21–22	23–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59
5 ft.	107	110	114	118	122	126	128	131	133	134	135
1 in.	112	115	118	121	124	128	130	133	135	136	137
2 "	117	120	122	124	126	130	132	135	137	138	139
3 "	121	124	126	128	129	133	135	138	140	141	142
4 "	124	127	129	131	133	136	138	141	143	144	145
5 "	128	130	132	134	137	140	142	145	147	148	149
6 "	132	133	136	138	141	144	146	149	151	152	153
7 "	136	137	140	142	145	148	150	153	155	156	158
8 "	140	141	143	146	149	152	155	158	160	161	163
9 "	144	145	147	150	153	156	160	163	165	166	168
10 "	148	149	151	154	157	161	165	168	170	171	173
11 "	153	154	156	159	162	166	170	174	176	177	178
6 ft.	158	160	162	165	167	172	176	180	182	183	184
1 "	163	165	167	170	173	178	182	186	188	190	191
2 "	168	170	173	176	179	184	189	193	195	197	198
3 "	173	175	178	181	184	190	195	200	202	204	205
4 "	178	180	183	186	189	196	201	206	209	211	212
5 "	183	185	188	191	194	201	207	212	215	217	219

In ascertaining height—measure in shoes; stand erect, and press measuring rod down against scalp. Weigh yourself in indoor clothing and shoes. Subtract one inch for height, if measured in shoes.

[1] Private communication, printed by permission of Thomas D. Wood, M. D., Professor of Physical Education, Columbia University.

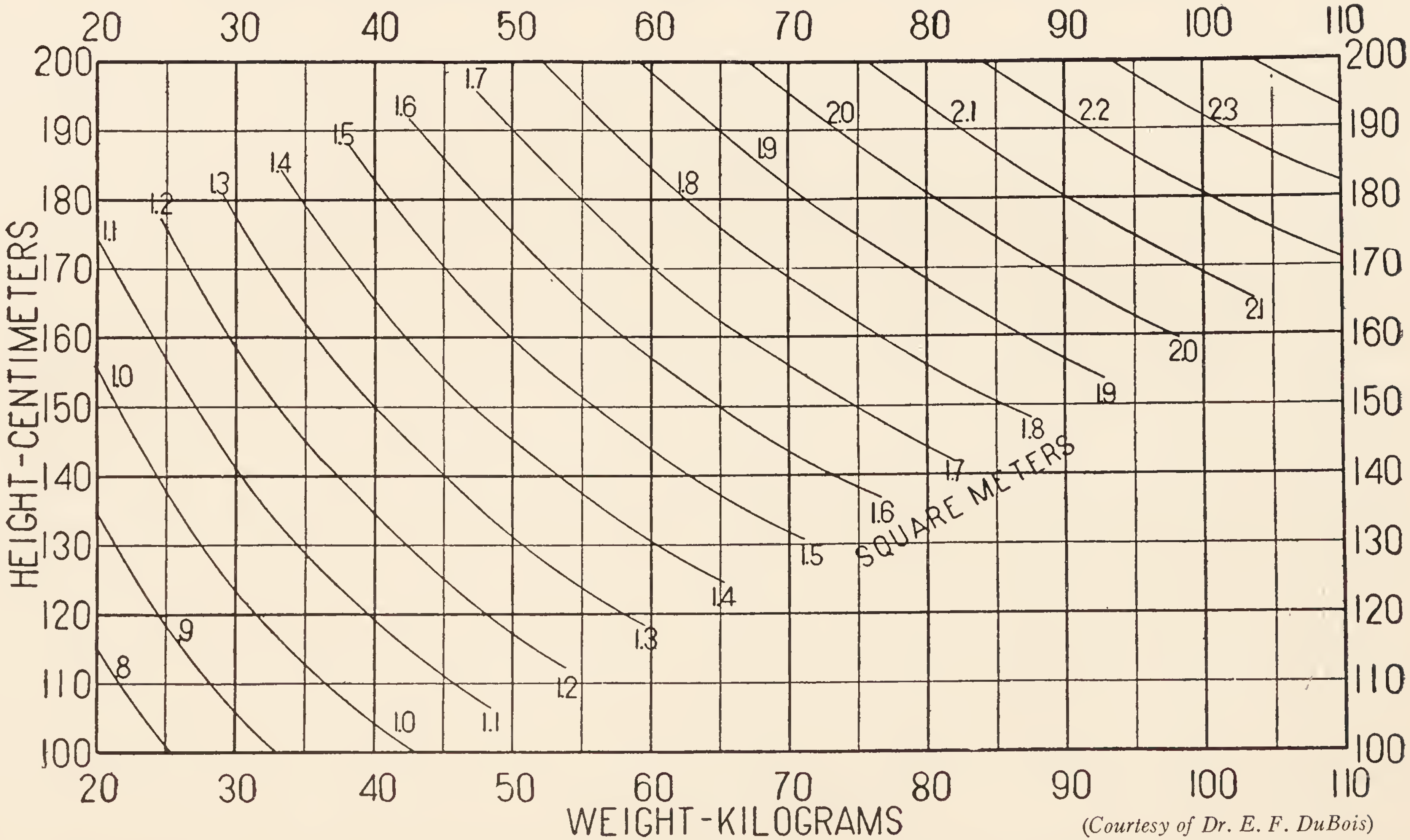
TABLE VIII

Table of Weight and Height for Women at Different Ages

Height	19 yrs.	20	21–22	23–24	25–29	30–34	35–39	40–44	45–49	50–54
4 ft. 10 in.	98	102	106	110	113	116	119	123	126	129
11 "	103	107	109	112	115	118	121	125	128	131
5 ft.	109	112	113	115	117	120	123	127	130	133
1 "	113	115	116	118	119	122	125	129	132	135
2 "	116	118	119	120	121	124	127	132	135	138
3 "	120	121	122	123	124	127	130	135	138	141
4 "	123	124	125	126	128	131	134	138	141	144
5 "	126	127	128	129	131	134	138	142	145	148
6 "	129	130	131	133	135	138	142	146	149	152
7 "	131	133	135	137	139	142	146	150	153	156
8 "	135	137	139	141	143	146	150	154	157	161
9 "	138	140	142	145	147	150	154	158	161	165
10 "	141	143	145	148	151	154	157	161	164	169
11 "	145	147	149	151	154	157	160	164	168	173
6 ft.	1 0	152	154	156	158	161	163	167	171	176

In ascertaining height—measure yourself in shoes; stand erect, and press measuring rod down against scalp. Weigh yourself in indoor clothing and shoes. If shoes have sensible heels, subtract one inch for height; if heels are "high," subtract two inches.

CHART FOR DETERMINING SURFACE AREA OF ADULTS FROM WEIGHT AND HEIGHT



(*Courtesy of Dr. E. F. DuBois*)

Express height in centimeters by dividing height in inches by 0.0394. Express weight in kilograms by dividing weight in pounds by 2.2. Place a ruler horizontally at the point corresponding to height in centimeters and another vertically at the point corresponding to body weight in kilograms. Where these two intersect place a dot. If this dot falls upon one of the curving diagonal lines, read the surface in square meters from the end of the line. If it falls between two lines estimate the distance on a line between them and perpendicular to them.

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